

NANOTECHNOLOGY:
Engines On

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Nanotechnology: Engines On

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ICN
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Nanoaracat
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CNBSS
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IMAGES:

Images on page 12 ("Van Gogh's Starry Night"), page 15 ("Puntillado"), and page 27 ("I'm so scared!"), were taken by Miriam Varón and Martí Busquets, from the Inorganic Nanoparticles Group at the Catalan Institute of Nanotechnology. These images were part of the 2010 National Scientific Photography Contest (FOTCIENCIA www.fotciencia.es) organized by the Consejo Superior de Investigaciones Científicas (CSIC) and the Fundación Española para la Ciencia y la Tecnología (FECYT). Their use in this book has been authorized by FOTCIENCIA.



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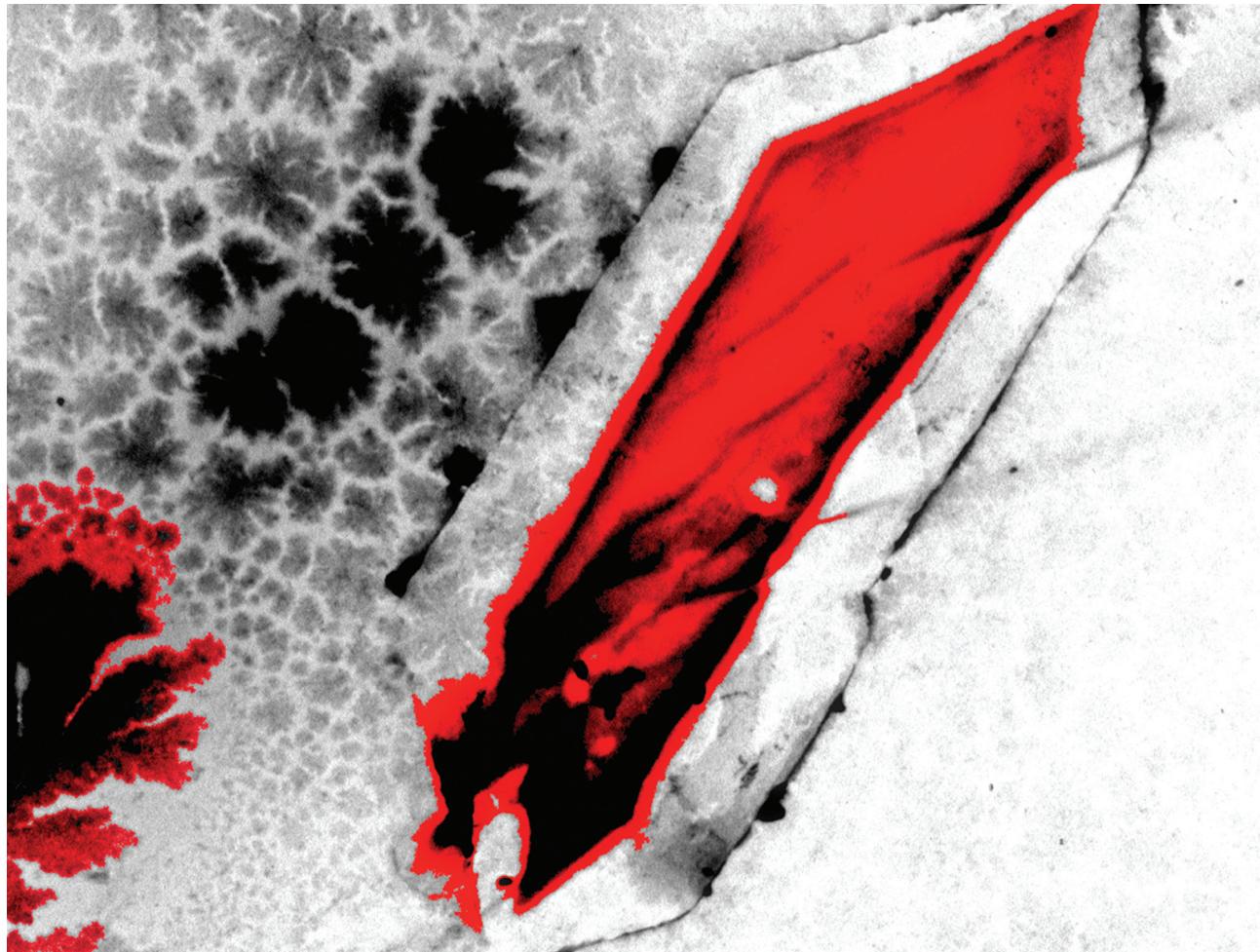


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NANOTECHNOLOGY: ENGINES ON

Nanotechnology and Energy



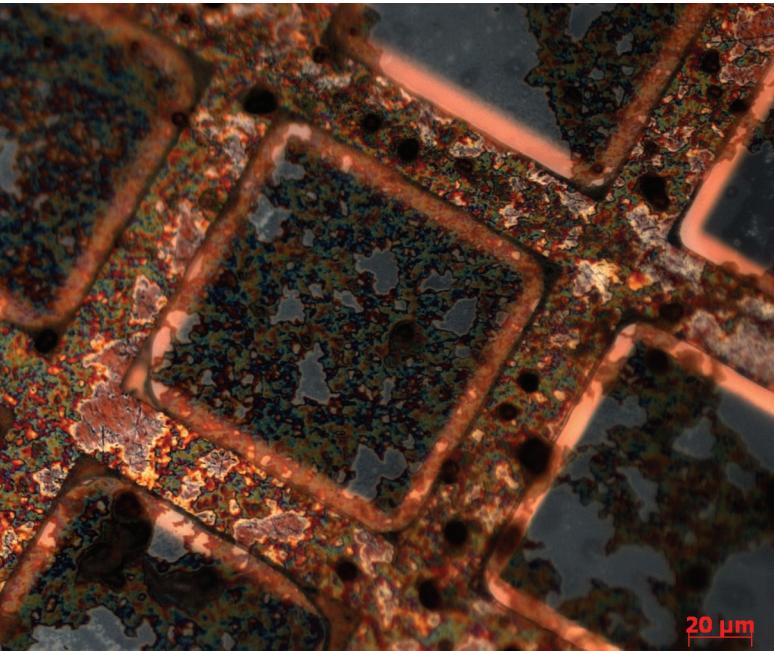
We would like to start the year by merging and blending some thoughts on recent news that appeared in our Nanowiki 2010, following the positive experience from last year's digest, "Nanotechnology, Balancing the Promises" [1], on the question of the unknown potential benefits to human health and environmental risks of nanotechnology. This year, the focus is on energy.

The responsible implementation of Nanotechnology should be a balance between the risks and benefits to society, as analyzed by a broad spectrum of stakeholders. Our intention is to promote the debate on the evolution of this young discipline,

nanotechnology, to ensure its safe and responsible development.

The text is accompanied by a selection of microscopy images which summarize our efforts within the laboratory to explore the world on the nanoscale during the last year. We investigated the interaction between nanoparticles and biological systems, basically synthesizing building blocks, metallic and oxide nanoparticles, alloys, and hollow nanostructures and studied their coating, which was either unspecific or specially designed to mimic biological structures or modify the biodistribution of anticancer drugs.

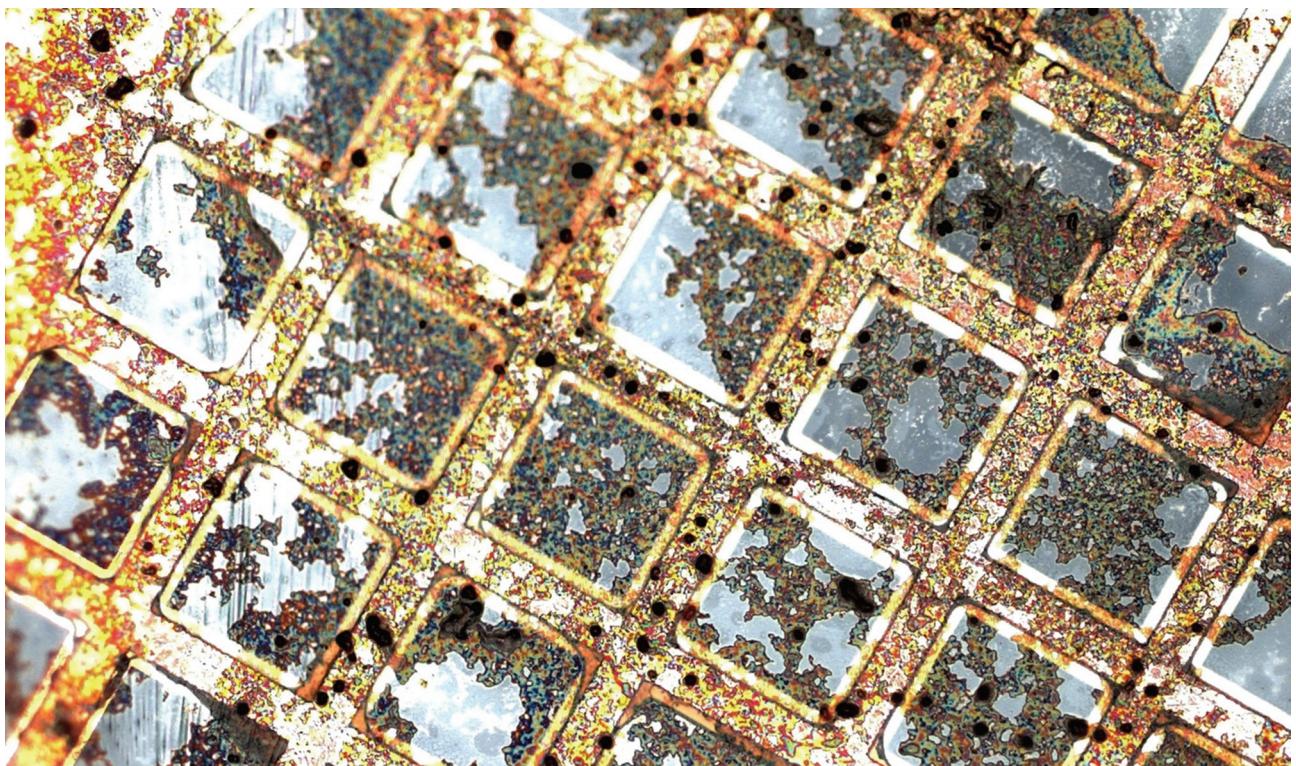
From Candles to Little Stars



To me, the alarm about the apparently coming energy crisis rose with the observation of climate perturbation, increase of atmospheric CO₂, and loss of ice mass some years ago. During this time we have seen the rise and fall of both the hydrogen and biodiesel miracles. Regarding hydrogen as an energy source, in my opinion, everything is fine except we don't have enough freely available hydrogen. On one hand, the energy balance between reducing water and oxidizing hydrogen is negative. On the other hand, the idea of the H-Bomb as a source of energy is somehow useless as "cold" fusion or the like is nothing but a dream. We hope that ITER (originally the International Thermonuclear Experimental Reactor) may release man from energy starvation but, they say [2], it may take up to 15 or 20 years to know if this will even be possible in the future. In addition, H₂ is dangerously unstable and has a low energy density when compared with commonly used fuels. The second miracle, biodiesel, is a renewed "fashion" for one of the oldest and the most-used

energy sources in all growing civilizations: burning wood (or its derivatives). It is a way to take back the Sun's energy stored in chemical bonds by means of photosynthesis, recovered when aggressively oxidized (thanks to the 20% oxygen concentration in the atmosphere). Apart from the socioeconomic problems arising from the substitution of forest and land used for food with crops for biodiesel, the process is, in the best case, CO₂ neutral, but as there are always entropic losses, it will probably not be neutral in reality. Besides, there is probably not enough fertile land to satisfy all of our energy hunger. Forests close to long-lived urban areas have been historically and systematically plundered, and maybe it was the sustained predation of the environment that made the "wanna-be-sedentary" men move from valley to valley, depriving the environment and colonizing the planet, as paleohistorians suggest. But Neolithic man started long ago and we are many, so we need not only plenty of energy, but to evolve as a society towards more sustainable models. Otherwise, even dramatic population shortages would only delay the final crash. Apparently we can easily figure out how to spend much more energy unless we are forced not to do so. Maybe there is much more oil than we think; I do not know if we can scan the planet from space and get a density map in which one can unequivocally detect oil and carbon, even that embedded in minerals, and then learn how to deal safely with it (no pollution, no CO₂ release). Maybe. Could we be wrong and have many other serious problems to contend with before this foreseen fossil-fuel drama occurs? Even with increasing population and high energy consumption? Maybe.

"A Huge Global Increase in Energy Use is Inevitable"



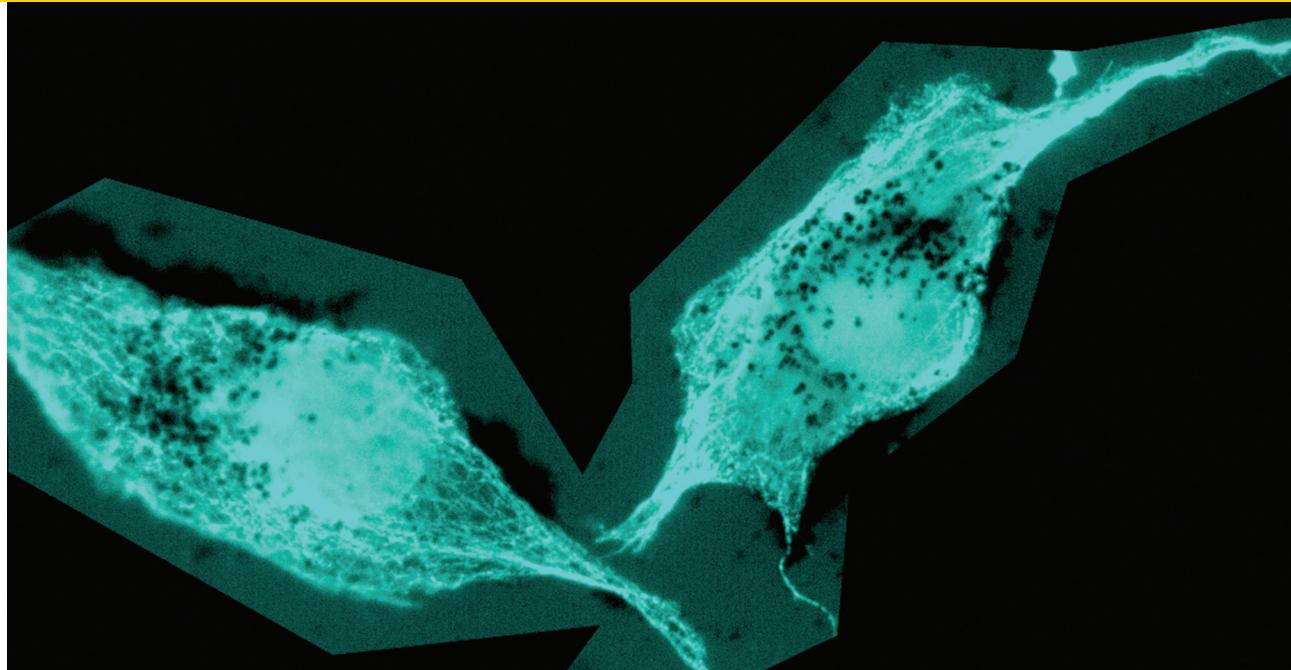
Back to ITER; as one opens its web site, the sentence: "a huge global increase in energy use is inevitable" welcomes, and disturbs, you. Maybe because of this, in 1996, when Richard Smalley obtained his Nobel prize for the chemical synthesis of the fullerenes, which he accepted as the first Nobel Prize specifically on Nanotechnology, he put aside his previous scientific career and openly used his pre-eminence to promote a new message: Scientists from all disciplines should focus on solving the pressing energy demands, pollution, and geopolitical issues before going back to their regular concerns. He especially focused on the use of the Sun's irradiation to relieve mankind from energy starvation. Years later, when Prof. Steven Chu was appointed as Secretary of Energy, the United States initiated a strong program on energy with a significant focus on nanotechnology, and thus special programs, centers, and offices have recently

been initiated around the globe. France also presented its own program on nanotechnology for energy and Germany and the EU followed later, which all indicates the critical importance of nanotechnology to solve our increasingly pressing energy-related problems: increased demand and pollution, quite apart from scarceness of resources and geopolitical instability. Thus, with peak oil approaching [3], when the demand for oil will surpass our ability to extract and distribute it, the need for sufficient, clean, and safe (not depending for its supply on politically unstable areas) energy is becoming one of society's major challenges. In many fields of energy (production, conversion, and storage), nanotechnology is specially positioned to be a fundamental piece of the energy solution, as foreseen by many research institutions. Japan and UK have also their own special programs on nanotechnology for energy.

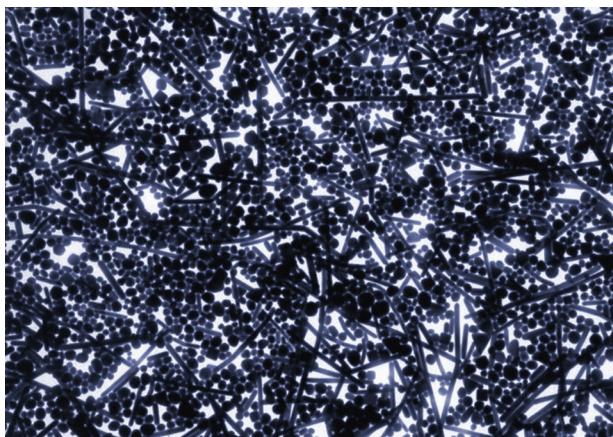
Controlling climate change, abandoning dependency on fossil fuels, and creating the conditions for sustainable development will require as great a transformation as our ancestors accomplished over tens of thousands of years in moving from agrarian to urban societies. [4] When re-reading the Origin of the Species by Darwin, on its 150th anniversary, one is struck by the lucidity and humility of the argumentation as well as the transformative power of its conclusions. Yet the scientific theory of evolution is still not widely understood or accepted by most people. Arrhenius first wrote about the impact of increasing CO₂ on global climate in 1896, and yet at the highest level of government the issue was still argued about until recently. Somehow the ambitious enlightenment projects of the Renaissance and the Scientific Revolution are still incomplete. Scientific knowledge is not culturally appropriated. Many people use cell phones for daily survival, but could not explain the difference between a photon and an electron. Governments want high technology employment

growth, but don't see why you need theoretical or fundamental scientists. One of the reasons for this is that common science does not make common sense. An interesting new development is a generation of artists that is collecting data about their world using scientific instruments, but employing the data for cultural purposes. Not only are they making powerful art, they are making science intimate, sensual, and intuitive. They are mixing science with the arts and humanities, which is essential to the cultural transformation necessary within the next two generations [5]. Indirectly, art works and art practice also train and nurture the brain. Artists project what their brains interprets from the world that scientist are trying to decode. Images of the world are built on mirror neurons. Thus, art becomes the Rosetta stone that links the brain with the world, and the supreme trainer. The emotions invoked by art expand the experience of nature and therefore promote knowledge and proximity of it, and care for it.

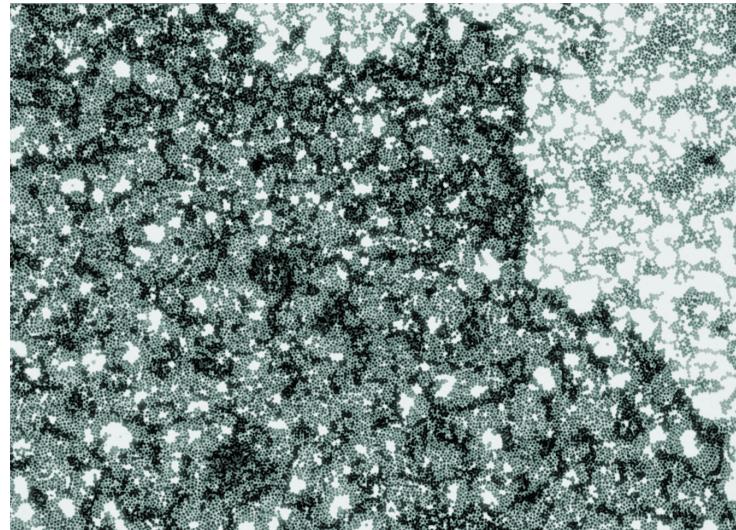
Roger F. Malina. Intimate Science and Hard Humanities. LEONARDO, 42(3), 184-184, 2009



Novel physical and chemical properties of nanomaterials can be applied and engineered to meet advanced material requirements in the new generation of energy production, conservation, and conversion devices. Nanomaterials have been familiar within various fields of energy in the past. For example, heterogeneous catalysts in the form of nanosized particles dispersed onto microporous supports have been applied to oil processing for many decades. The tremendous advances in modern nanotechnology are reflected in the expanded ability to design and control materials, their size, shape, chemical composition, and assembly structure. Nowadays, well-controlled synthesis of nanomaterials and nanoscale characterization enables us to unambiguously correlate the structural properties of matter with its physical, chemical, and biological properties. For example, fuel cells and batteries, such as polymer-electrolyte-membrane fuel cells, solid-oxide fuel cells, and lithium batteries are electrochemical systems for conversion between chemical energy and electricity. They consist of an anode and a cathode separated by an electrolyte. A pair of reduction and oxidation reactions on the electrode surface results in electric current generation. Application of nanoparticles may significantly improve the efficiency of fuel cells and the energy-stor-



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age density of batteries. Thermoelectric materials tailored at the nanoscale may efficiently convert waste heat generated by combustion engines into electricity, which improves the overall energy efficiency of engines.

There are also examples of nanomaterial use in lighting. Lighting uses about 20% of the total electricity generated worldwide, thus development of advanced lighting devices with good luminous efficiency will have significant impact on energy consumption.

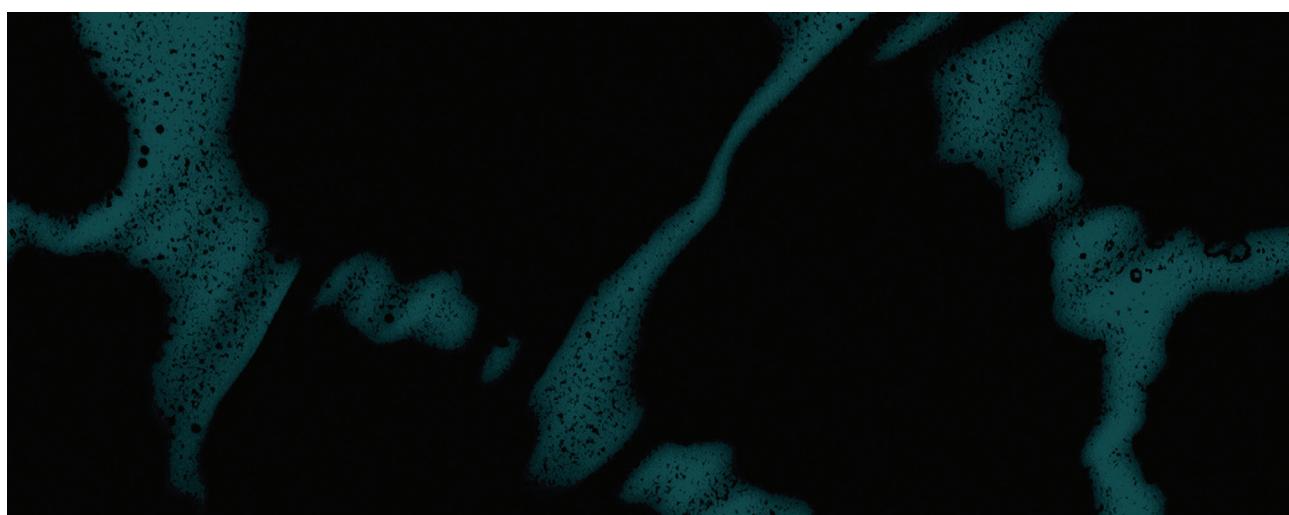
Catalysis also plays an important role in the technologies for transportation, energy production from fossil fuels or alternative energy resources, bulk chemical production, and pollution control, where efficient and selective chemical conversion processes are of great concern. Thus, advances in nanoscience provide opportunities for developing next-generation catalytic systems with high activities for energetically challenging reactions, high selectivity valuable products, and extended life times that improve efficiency with respect to energy production and consumption. The selective conversion of biomass-derived carbohydrates into liquid fuels and valuable chemicals is a key step in the conversion of biomass. Additionally, the technology thus developed can also be applied to degrade persistent organic pollutants in environmental remediation [6].

Energy In, Energy Out

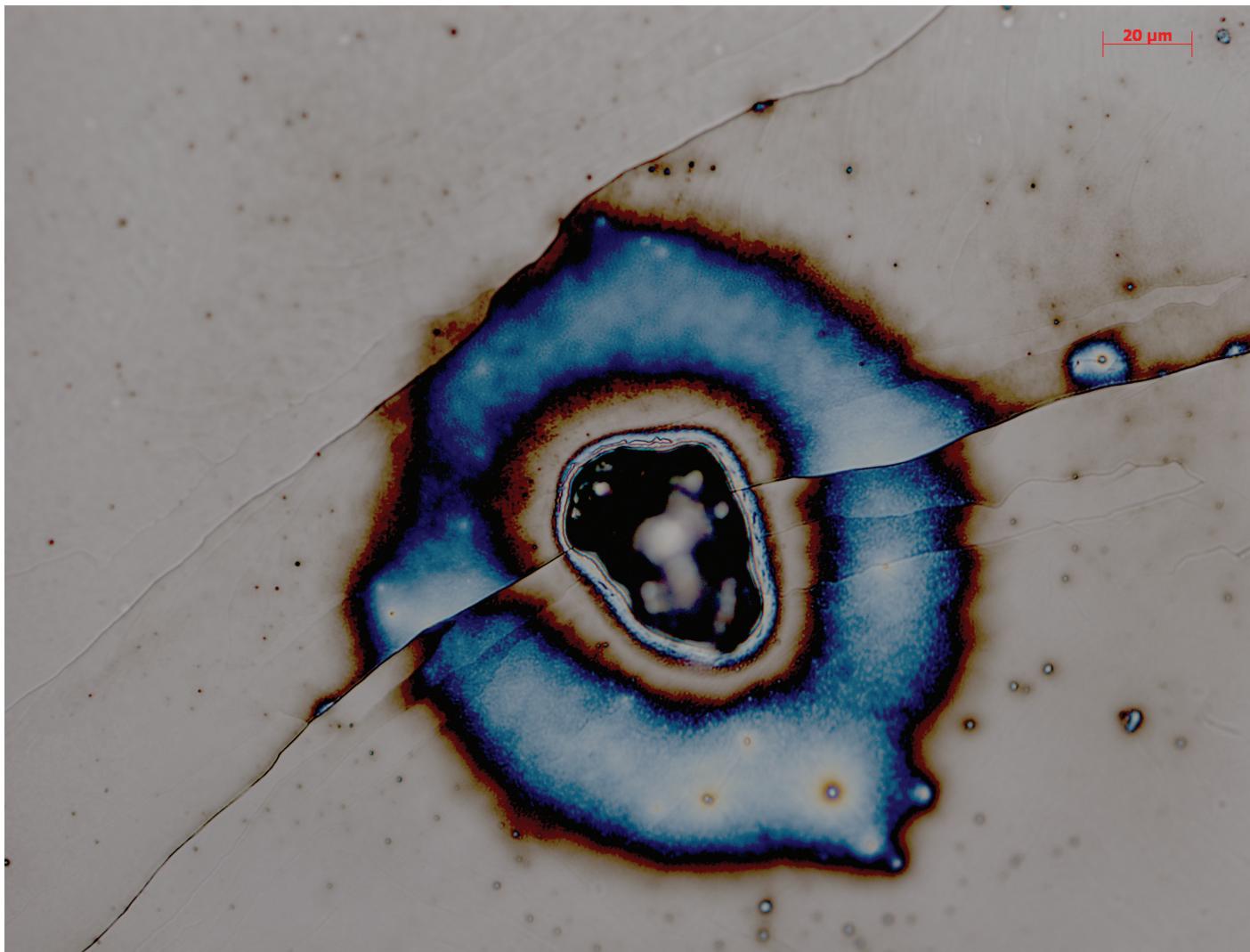
At present, developing efficient and clean energy technologies is an urgent task that is crucial to the long-term energy and environmental security of our society. Energy conversion and transport in nanomaterials differs significantly from those in bulk materials because of the difference in effect of classical and quantum-size effects on energy carriers such as photons, phonons, electrons, and molecules. Nanoscience for energy applications is now focused on tailoring these nanoscale effects for efficient energy technologies such as photovoltaics, photochemical solar cells, thermoelectrics, fuel cells, photoelectrochemical cells, batteries, and so forth. For example, solar energy has been considered the cleanest and most renewable energy source (under ideal conditions, radiation power on a horizontal surface is 1000 W/m^2). High-energy photons are absorbed in the atmosphere leaving UV-visible light in the higher energy range). Efficient light absorption to generate charge carriers - an electron or its counterpart, a hole - in a solid occurs on the scale of several hundreds of nanometers (equivalent to the wavelength of visible light). Electrons travel short distances before being trapped. The mean free path of the excited charged carrier is much shorter than the wavelength of light.

To achieve efficient photon absorption and collection of excited charge carriers in a photovoltaic device, an optimal design should be a low-dimensional nanostructure, such as semiconductor nanowires, in which at least one dimension is larger than the wavelength of light and another dimension shorter than the mean free path of the charge carriers, as is the case in photosynthesis. While photovoltaic cells directly convert photonic energy into electricity by separating the excited electron–hole pairs in photovoltaic materials, photoelectrochemical cells use the excited electrons and holes to catalyze redox reactions, which may split water or CO_2 to generate fuel. So far, photovoltaic and photoelectrochemical cells have not made a strong contribution to energy supply because of their currently low conversion efficiencies.

The research reported this year relating to energy can be clustered into a few main fields such as photovoltaic devices and photosynthesis, batteries, fuel cells, and carbon dioxide management. Carbon dioxide may be responsible for climate change and if the climate does change we may require even more energy to survive, unless we adapt.



Inside the Glass-House: CO₂ in the Short Term



It makes sense, before focusing all our efforts on substituting the energy system, to deal with the consequences of the current one if necessary. It would be irresponsible to allow all the oil to be burned, just because it will not be as easily available for much longer. Peak oil is indeed expected to occur not very late in this century.

Earth's carbon cycle is overburdened. We emit more carbon into the atmosphere than natural processes are able to remove - an imbalance with negative consequences. The Carbon Cycle 2.0 project [7] also

means collaboration 2.0; tackling one of the greatest challenges facing the world will require an urgent and more creative take on the kind of cross-disciplinary problem-solving needed to bridge the gap between basic and applied research. These are small steps worth taking. The initiative aims to become an umbrella under which all interested stakeholders can meet and discuss, share and cooperate.

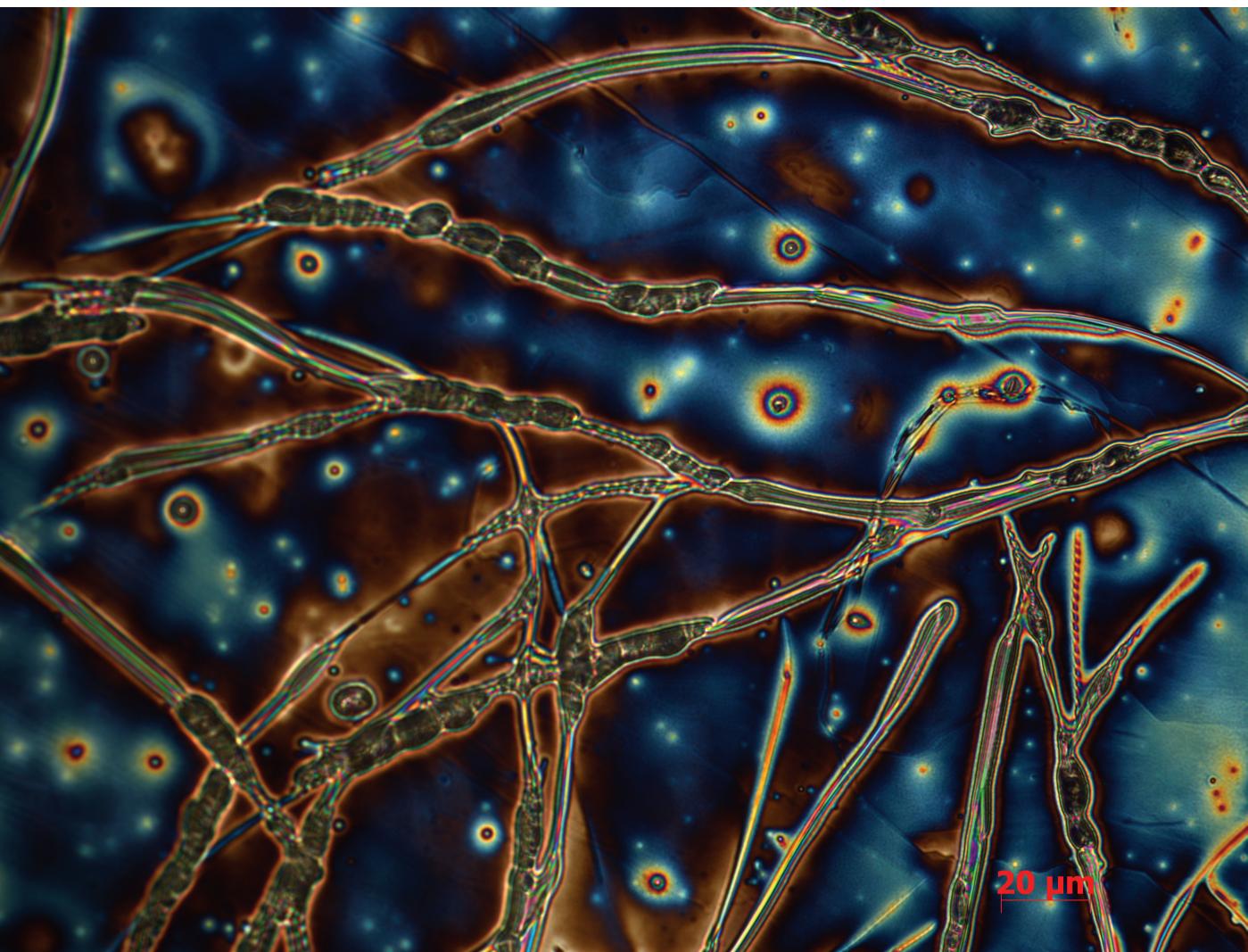
Among the many proposals, "Crystal Sponges to Capture CO₂" is an interesting one [8]. Scientists reported the "ulti-

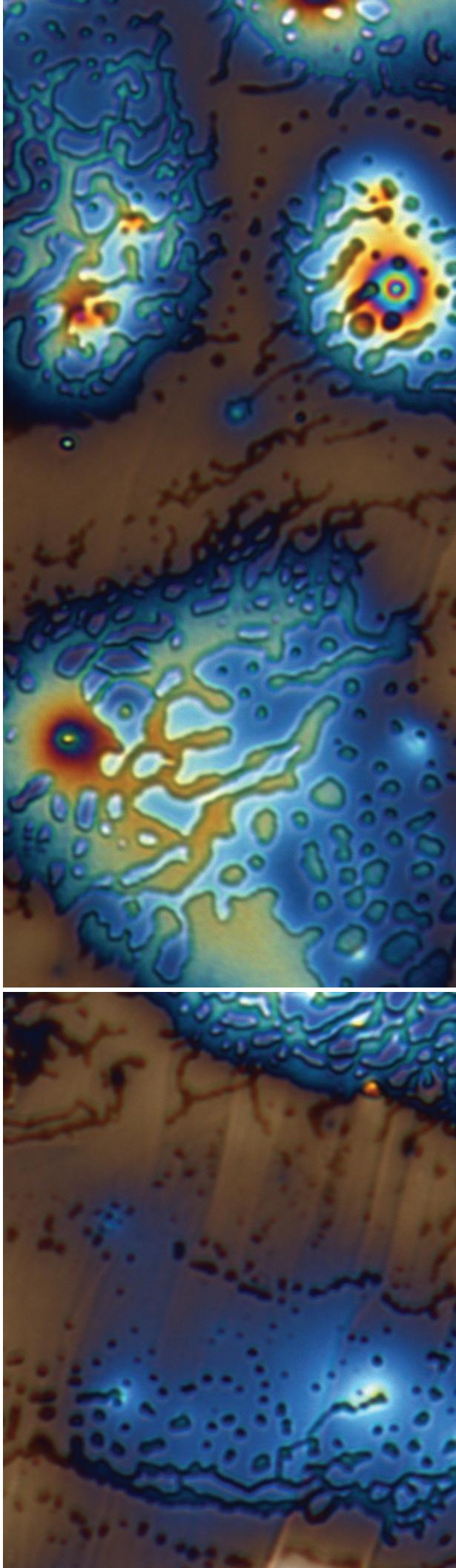
mate porosity of a nanomaterial”, which achieved world records for both porosity and carbon-dioxide storage capacity in an important class of materials known as MOFs, or metal–organic frameworks. MOFs, sometimes described as crystal sponges, have pores — nanoscale openings which can store gases that are usually difficult to store and transport. Porosity is crucial for compacting large amounts of gases into small volumes and is an essential property for capturing carbon dioxide. The concentration of CO₂ in the atmosphere is 388 ppm, by volume, in the

sponge it can be 478 000 ppm, over three orders of magnitude greater, thus we only need a piece of composite about the size of one thousandth of an atmosphere to capture it all; though we do not need to do this, it is nice to know that the volume of the atmosphere is a little over a quarter of a trillion cubic kilometers (although the distribution of CO₂ throughout the atmosphere is not even).

Absorbing and capturing CO₂, in sponges, phytoplankton, or forests is necessary but in my humble opinion it does not con-

Van Gogh's Starry Night. Image winner of the 2010 National Scientific Photography Contest (FotCiencia) organized by the Consejo Superior de Investigaciones Científicas (CSIC) and the Fundación Española para la Ciencia y la Tecnología (FECYT).





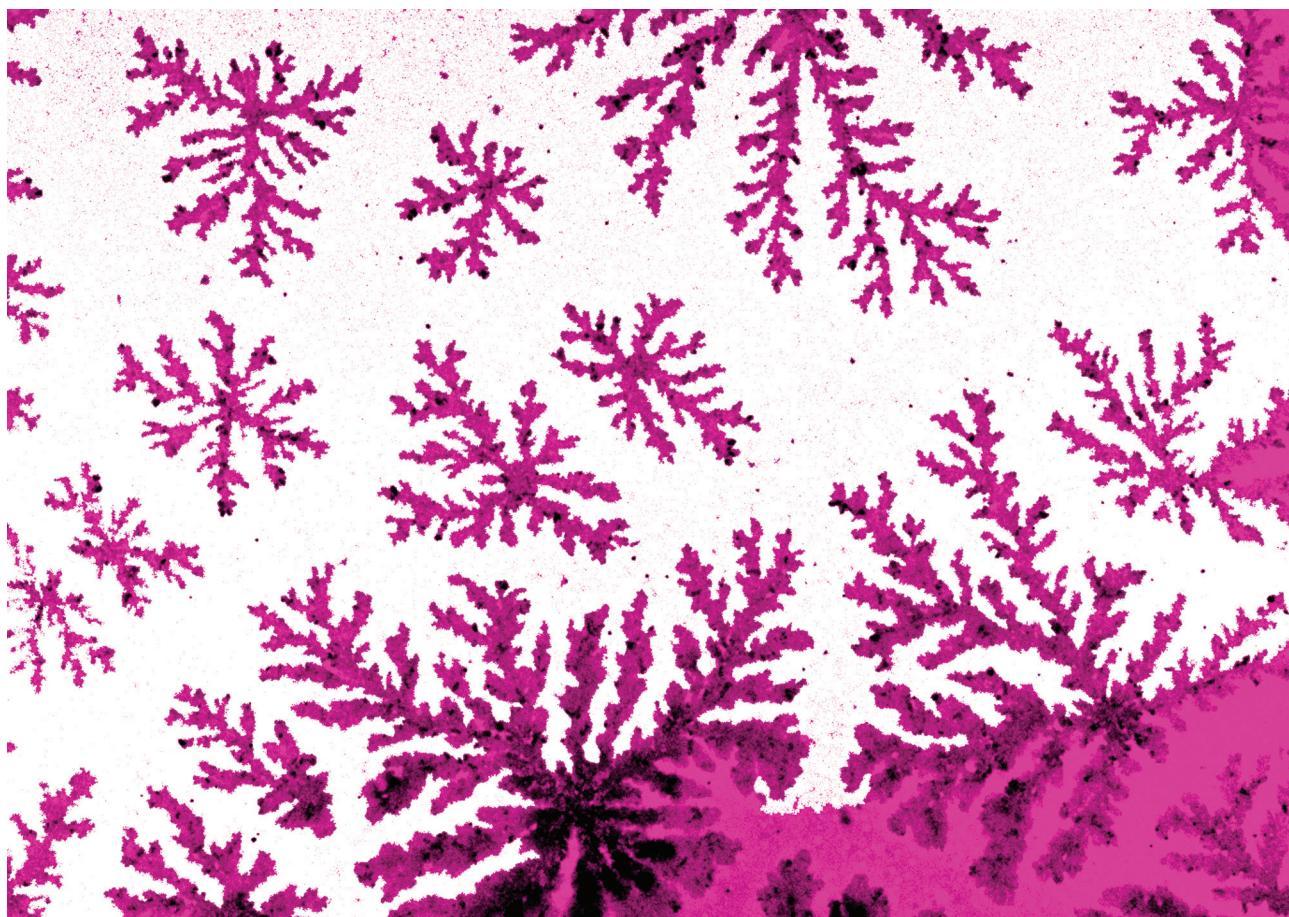
tribute to solving the energy shortage, although it could help to avoid the climate-change drama. Research could lead to cleaner energy and the ability to capture heat-trapping carbon dioxide emissions before they reach the atmosphere and contribute to global warming, rising sea levels, and the increased acidity of the oceans, researchers have reportedly said. Regarding rising sea levels, we have to subtract the Arctic from the calculations as it is effectively a giant ice-cube; since ice is less dense than water, it floats. From childhood, we may remember how a glass full of water with a floating ice cube does not overflow when the cube has melted to form extra water, because Archimedes was right and ice is less dense than water.

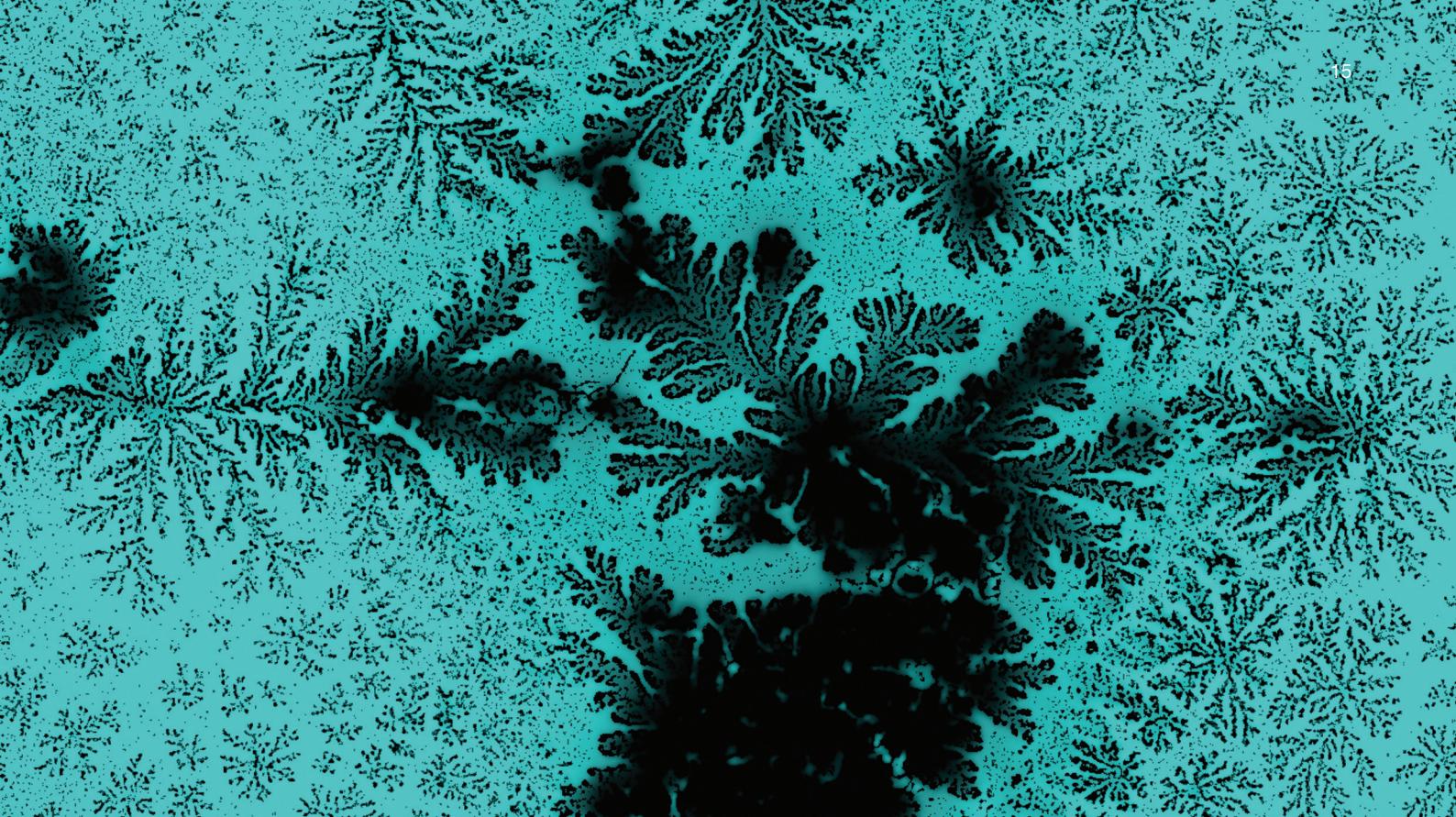
Regarding the waste from managing CO₂ and other energy needs, a Green Carbon Center has been created to bring together the benefits offered by oil, gas, coal, wind, solar, geothermal, biomass, and other carbon energy sources in a way that will not only help ensure the world's energy future but also provide a means to recycle carbon dioxide into useful products [9]. Scientists state that, whether or not one believes in anthropogenic climate change, humans are throwing away a potentially valuable resource with every ton of carbon dioxide released into the atmosphere. If we learned how to turn carbon dioxide into a useful molecule, this waste could be transformed into raw materials. This initiative addresses the very near future of energy with a focus on "green carbon" and the technological know-how to back it up. In the areas of more intense production and consumption of fossil fuels, researchers are better placed to address these issues.

Watching Plants Grow

Photosynthesis is a marvellous example of how to use and store energy from the Sun; studying it will help us to better understand energy processing, and therefore it is a hot topic in current science. Photosynthesis is the process by which green plants convert sunlight into electrochemical energy. Researchers have recorded the first observation and characterization of a critical physical phenomenon behind photosynthesis known as quantum entanglement [10]. When two quantum-sized particles, for example a pair of electrons, are “entangled”, any change to one will be instantly reflected in the other, no matter how far apart they might be. Though physically separate, the two particles act as a single entity. The results of this study hold implications not only for the development of artificial photosynthesis systems

as a renewable nonpolluting source of electrical energy, but also for the future development of quantum-based technologies in areas such as computing — a quantum computer could perform certain operations thousands of times faster than any conventional computer. Fascinatingly, entanglement can exist and persist in the chaotic chemical complexity of a biological system at room temperature. Scientists have presented strong evidence for quantum entanglement in noisy nonequilibrium systems at high temperatures by determining the timescales and temperatures at which entanglement is observable in a protein structure that is central to photosynthesis in certain bacteria. Green plants and certain bacteria are able to transfer the energy harvested from sunlight through a network of light-harvesting

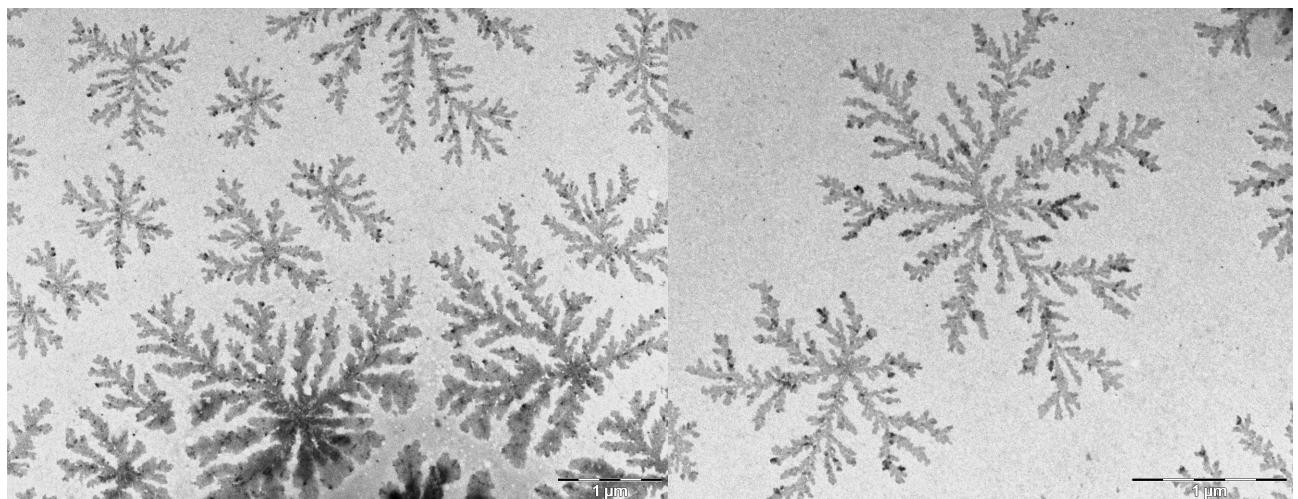




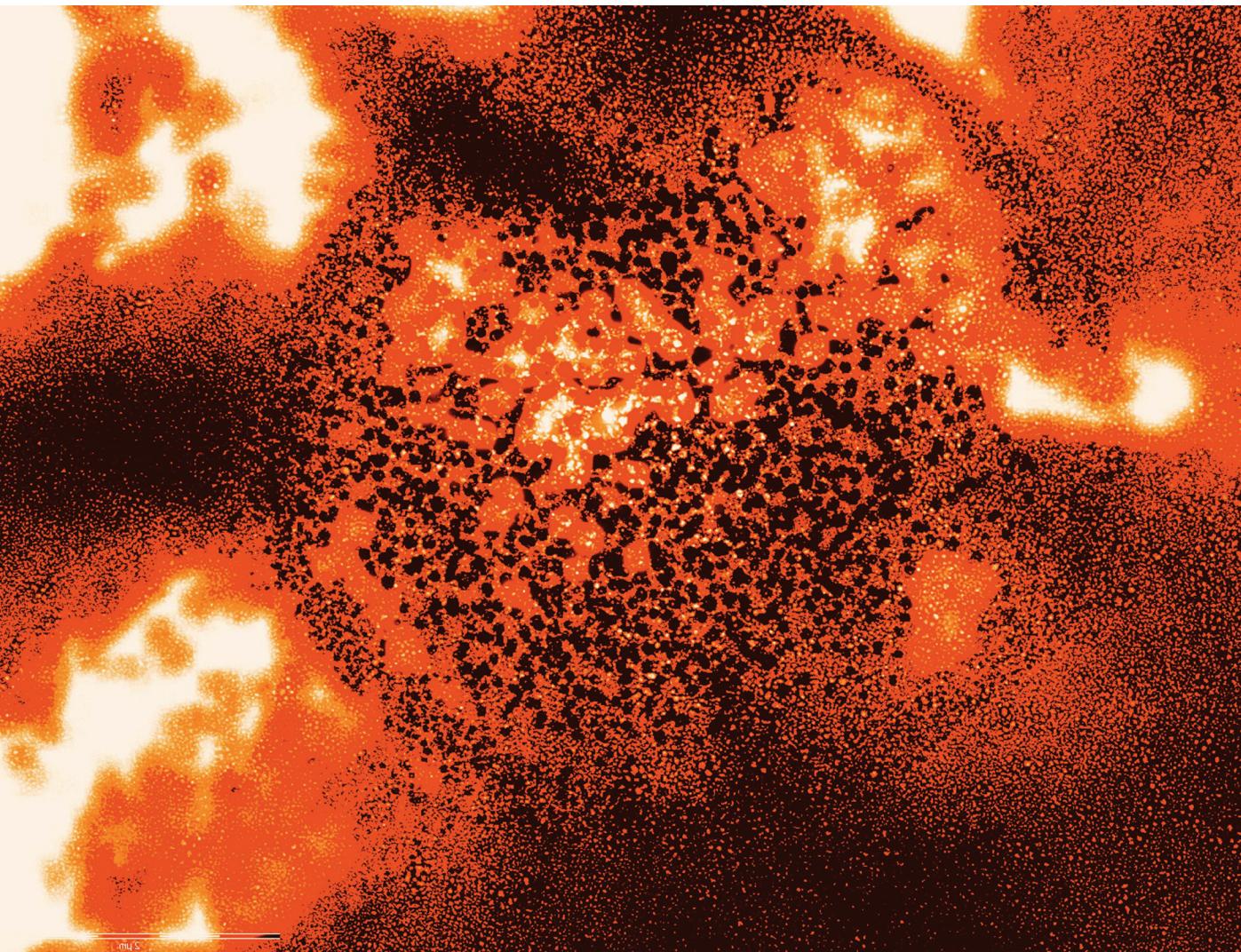
pigment–protein complexes and into reaction centers with nearly 100% efficiency. Speed is the key; transfer of the solar energy takes place so fast that little energy is wasted as heat.

In related news, nanotechnologists used the photosynthetic system of bacteria to transport light over relatively long distances. They developed a type of “molecular glass fibre” a thousand times thinner than a human hair, made of light-harvesting-complex proteins [11]. These proteins transport the sunlight within the cells of plants and bacteria to a place in the cell

where the solar energy is stored. We can learn a lot from nature in experiments such as this. When we understand how nature works, we can then imitate it. Using the Sun’s energy, in increasing in quantity and efficiency is a subject of intense research and generates large and ambitious multidisciplinary collaborative projects. One example of these is the ongoing Helios Project that aims at using nanotechnology in the efficient capture of sunlight and its conversion into electricity to surpass current economical fuel-production processes [12].



Creating Energy from Sunlight



In order to replace fossil fuels, we need to become a lot more proficient at harvesting sunlight and converting it into forms of energy that can be used for transportation and other human needs. Nature provides a model solution to this problem in photosynthesis. Together with Helios, a new Energy Innovation Hub has been created aimed at developing revolutionary methods to generate fuels directly from sunlight [13], that is, to bring together leading researchers in an ambitious effort aimed at simulating nature's photosynthetic apparatus for practical energy production. The goal of the Hub is to develop an

integrated solar energy into chemical fuel conversion system and move this system from the bench-top discovery phase to a scale on which it can be commercialized. This broad and complex research will be directed at the discovery of the functional components necessary to assemble a complete artificial photosynthetic system: light absorbers, catalysts, molecular linkers, and separation membranes.

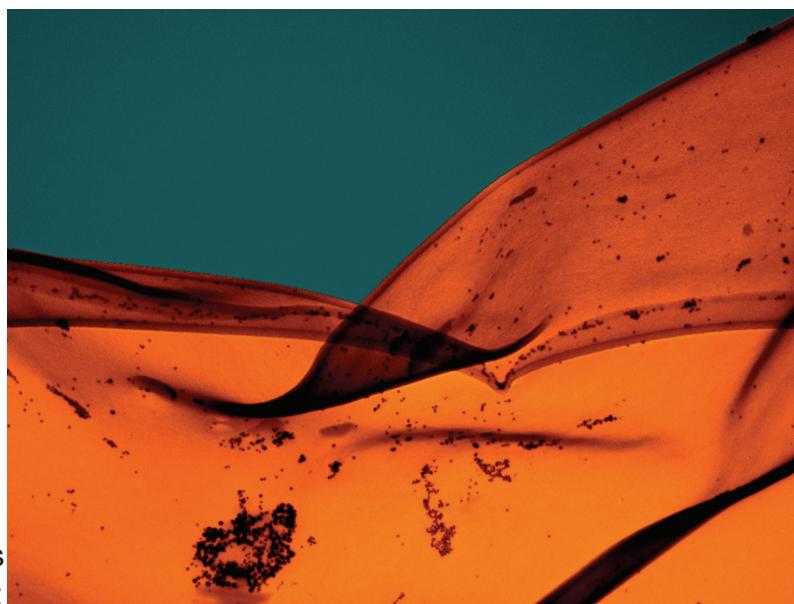
As stated, the most obvious energy source is the Sun, the origin of almost all the energy found on Earth. Simply, the biosphere consists of a discontinuous layer

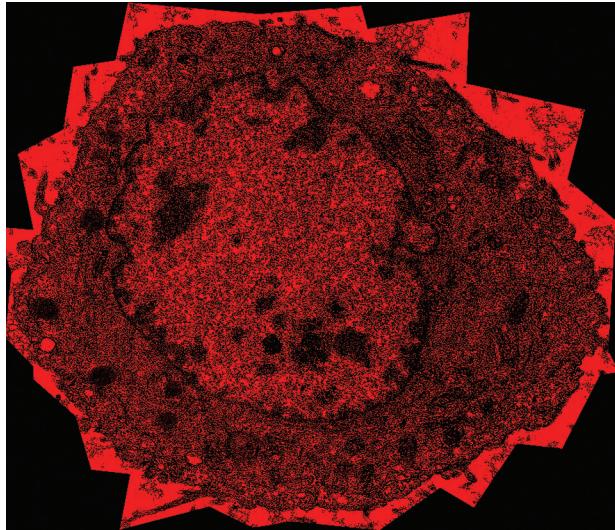
of organic matter spread onto a rock with a melted core floating in space and being toasted by the Sun. The surface of the Earth receives solar radiation energy at an average of 81,000 terawatts, which exceeds the whole global energy demand by a —mere — factor of over 5,000. Yet, we are still figuring out a cost-effective way of harnessing it to avoid driving Earth into extreme cold and darkness in a future where solar panels shadow the planet.

In addition, it is clear that if the energy used to produce the “energy-source device” is more than that the device will deliver during its full life cycle, then the device is not an energy source but simply an energy buffer and carrier. This may happen when the energy employed purifying silicon is greater than that recovered during the full life of the photovoltaic cell in which it is used. Thus, an important advance was reflected in the 2010 Millennium Prize to the father of third-generation dye-sensitized solar cells [14]. Grätzel cells, which promise electricity-generating windows and low-cost solar panels, are a third-generation photovoltaic technology. Such cells have just made their debut in consumer products. The excellent price/performance ratio of these novel devices gives them major potential as significant contributors to the diverse portfolio of future energy technologies. Grätzel cells are likely to have an important role in low-cost, large-scale solutions for renewable energy. Beyond photovoltaics, the concepts of Grätzel cells can also be applied in batteries and hydrogen production. This technology, often described as “artificial photosynthesis”, is a promising alternative to standard silicon photovoltaics. The cells are made of low-cost materials and do not

need elaborate apparatus to manufacture them. They are based on a semiconductor formed by a photosensitized anode and an electrolyte; a *photoelectrochemical* system. Because it is made of low-cost materials and does not require elaborate apparatus to manufacture, this cell is technically attractive. Likewise, manufacture can be significantly less expensive than older solid-state cell designs. The cell can also be engineered into flexible sheets and is mechanically robust, requiring no protection from minor events like hail or tree strikes.

One of the problems when dealing with sunlight is that the Sun’s rays can be highly destructive to many materials. Sunlight leads to a gradual degradation of many of the systems developed to harness it. But plants have adopted an interesting strategy to address this issue: They constantly break down their light-capturing molecules and reassemble them from scratch, so the basic structures that capture the Sun’s energy are, in effect, always brand

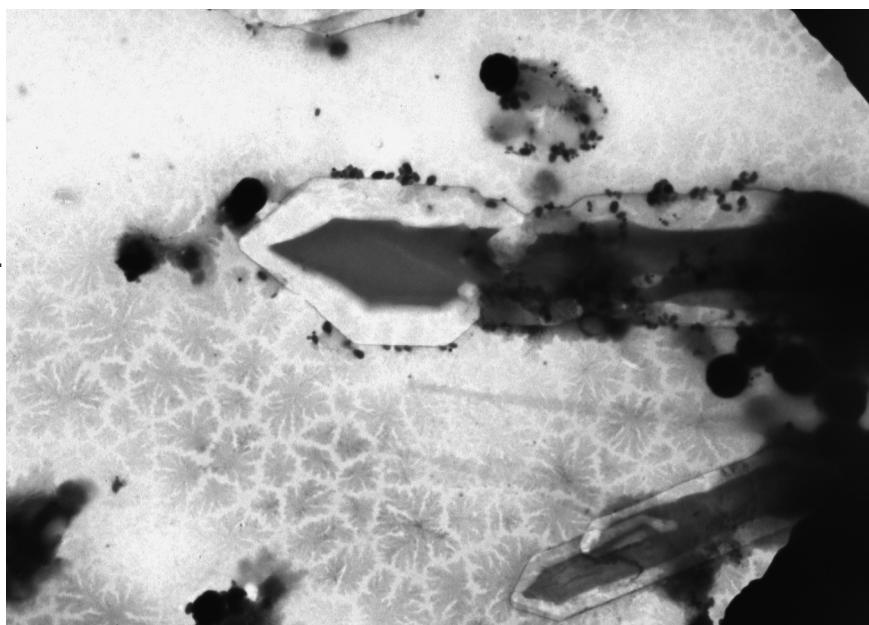




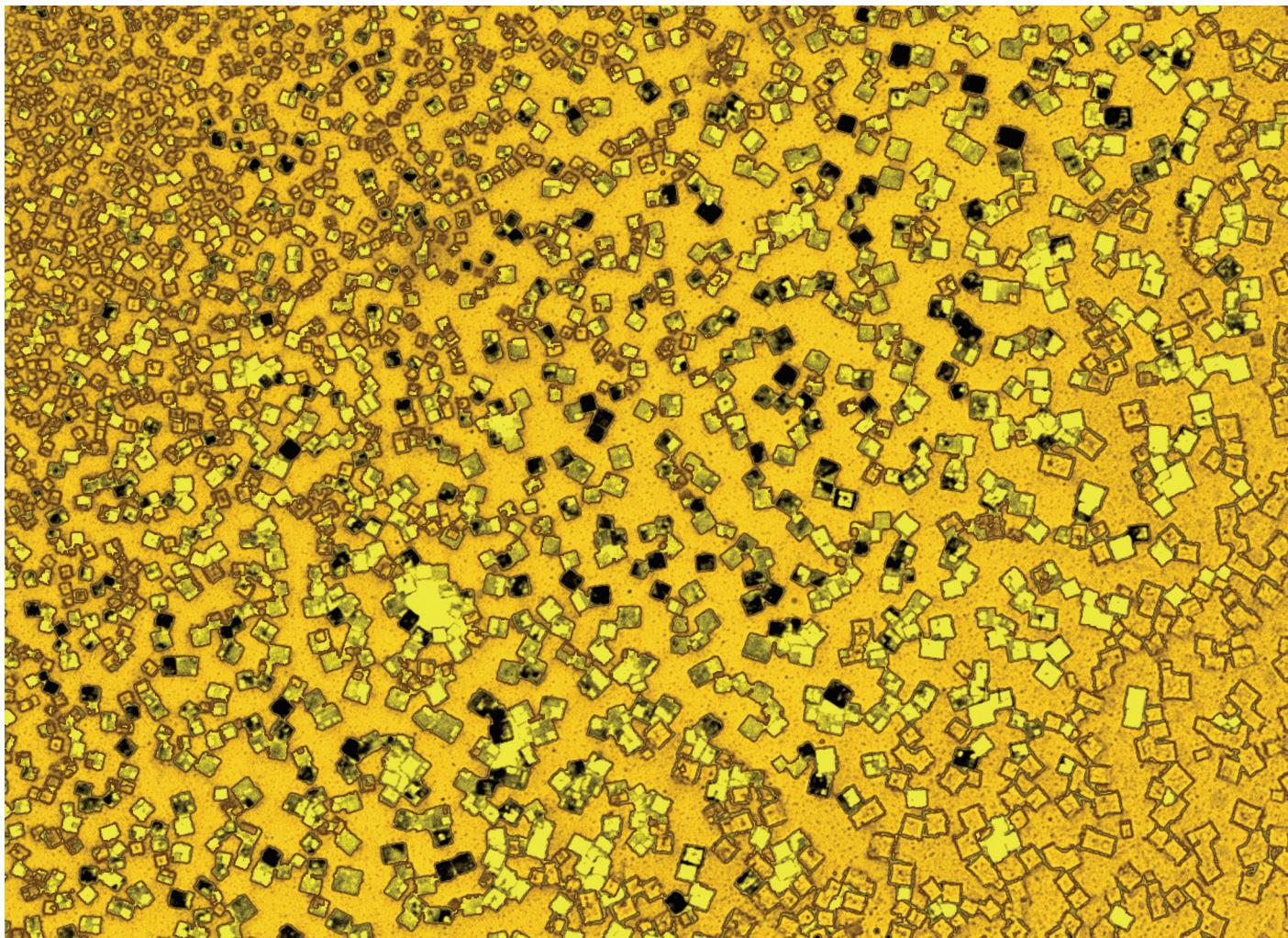
new. Thus, researchers have proposed a self-assembling photovoltaic technology that repairs itself [15]. Their proposal is a novel set of self-assembling molecules that can turn sunlight into electricity; structures that can be repeatedly broken down and then reassembled quickly, just by adding or removing an additional solution. Researchers were fascinated by the extremely efficient repair mechanism of plant cells. In full summer sunlight, a leaf on a tree recycles its proteins about every 45 minutes. To imitate photosynthesis, synthetic phospholipids that form discs have been produced; these discs provide structural support for other molecules that actually respond to light, which release electrons when struck by photons of visible light. The discs, which carry the reaction centers, are in a solution where they attach themselves spontaneously to carbon nanotubes. The nanotubes hold the phospholipid discs in a uniform alignment so that the reaction centers can all be exposed to sunlight at once, and they also act as wires to collect and channel the flow of electrons created by the reactive molecules. The system disintegrates when a surfactant is added to the solution. When the surfactant is removed by pushing the solution through a membrane, the compounds spontaneously re-assemble once again into a perfectly formed, rejuvenated photocell.

In the new assembly damaged proteins will be excluded and assembly misconformations removed. It is likely that one would need to feed the system new molecules from time to time... as is the case in biological systems.

For the many materials proposed, there persists the intention to explore the production of thin films (organic or inorganic) for photovoltaic technology. Of course, it is the surface that is exposed to the Sun, and the bulk is shaded from it. However, I find the recurrence of the idea to turn windows into power generators curious. Why windows? Because they are very flat, processable in decent sizes, present in almost any building and exposed to the Sun, I suppose. Researchers even remark that a solar cell made of nanoparticles is a thin film that absorbs only about the 10% of the visible light falling on it, and acting mainly in the UV, so its is highly transparent and allows the coverage of many things without changing their aspect [16]. Also, since it is a thin film that can be coated onto large areas, it could become very much cheaper than conventional devices.

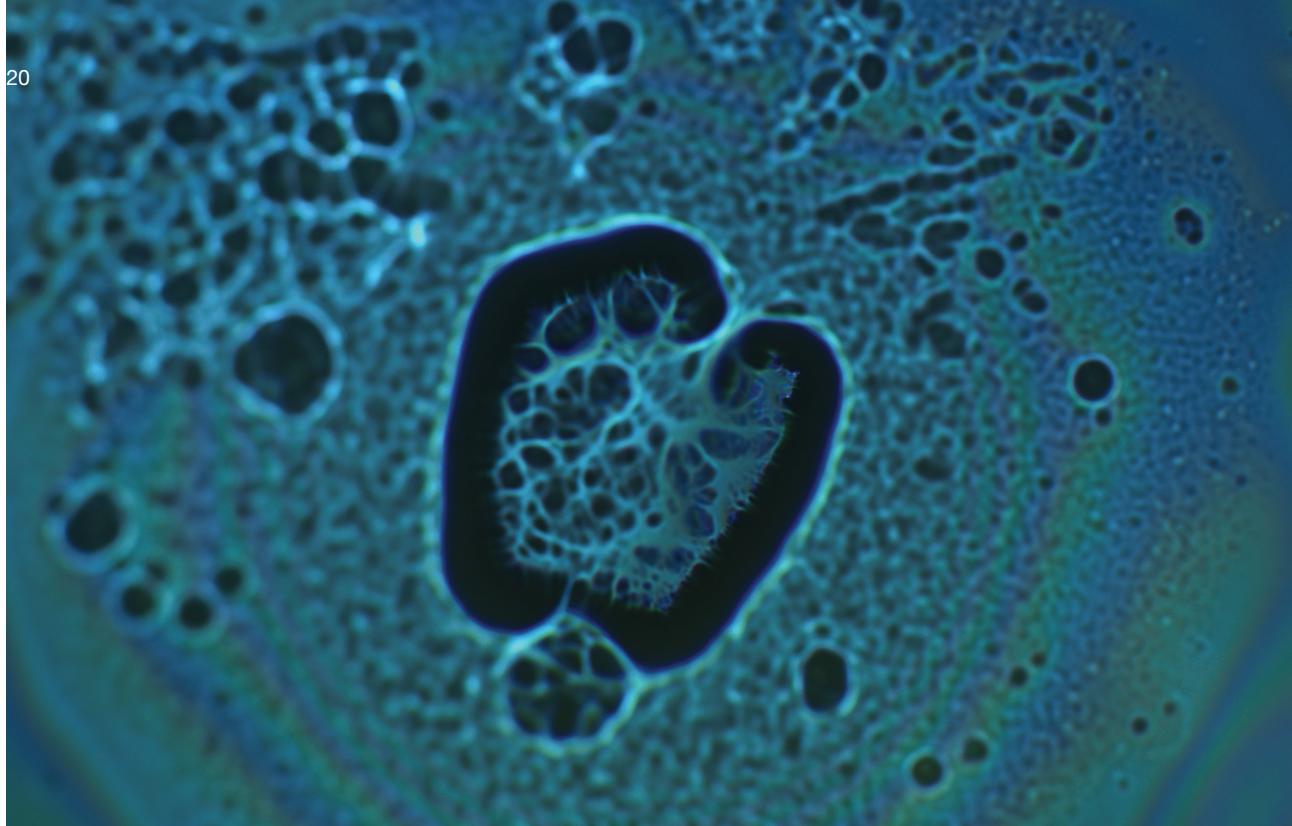


The Energy Store



In principle, an automobile is a nonsustainable concept; Fordians dreams of one man, one car require too much metal and oil. But it is pretty well designed in many respects. It uses the energy it generates, and generates the energy it needs. Storing fuel is easier than storing energy. However, if the device can not host an energy-on-demand production system as a combustion motor, it will need to store it. Sometimes, energy has to be converted, stored, and converted again, with significant energy losses. One of the main research activities of the last 12 months has been a focus on batteries.

When thinking about the future, someone of my age could have expected to have flying cars by 2010, but in absence of that, a car of the future powered by its body-work is not that bad. A composite blend of carbon fibres and polymer resin is being developed that can store and charge more energy, faster than conventional batteries can [17]. At the same time, the material is extremely strong and pliant, which means it can be shaped for use in building the car's body panels. Imagine a car whose body also serves as a rechargeable battery; a battery that stores braking energy while you drive and that also stores energy when you plug in the car overnight to

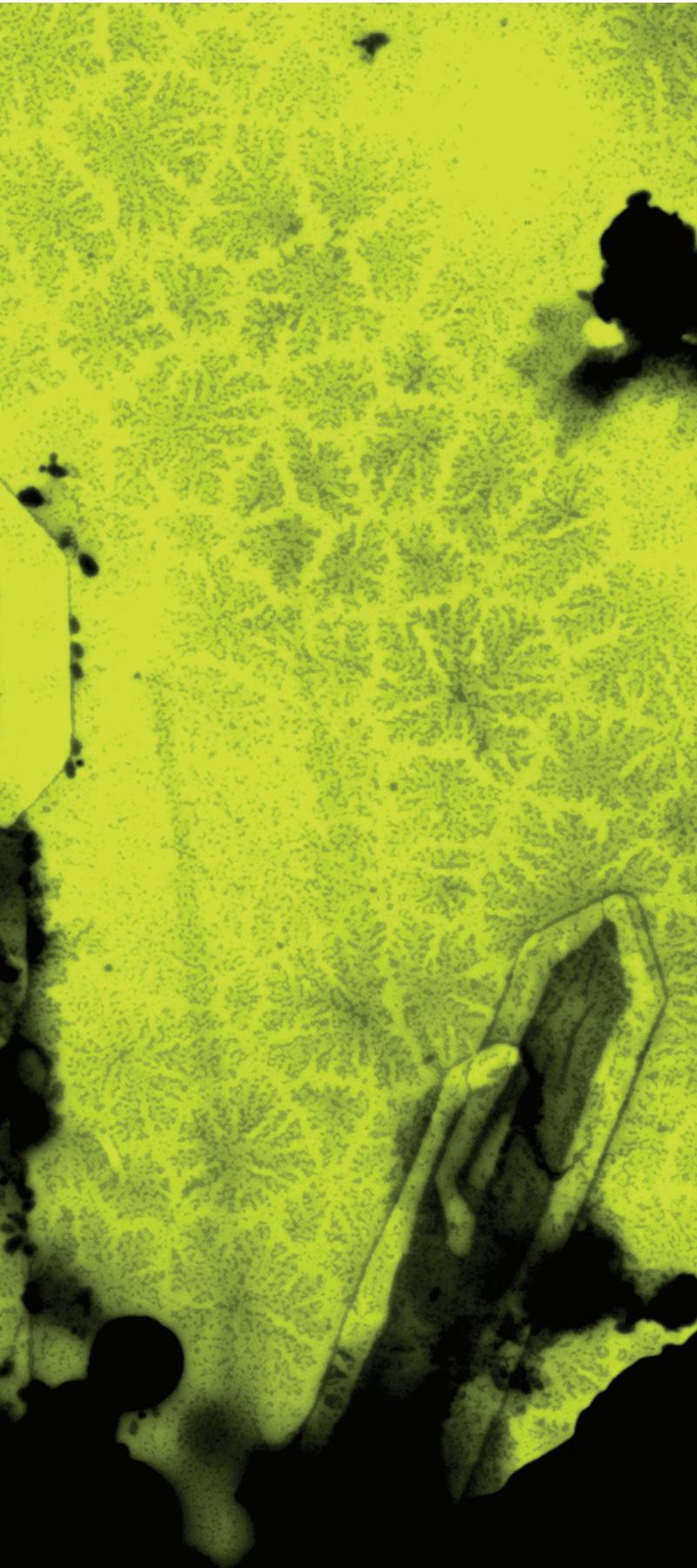


recharge. If those projects are successful, there are many other possible application areas. For instance, mobile phones will be as slim as credit cards and laptops will manage longer without needing to be recharged. The composite materials being developed, which are made of carbon fibres and a polymer resin, will store and discharge large amounts of energy much more quickly than conventional batteries. In addition, the material does not use chemical processes, which makes it quicker to recharge than conventional batteries. Furthermore, this recharging process causes little degradation in the composite material, because it does not involve a chemical reaction, whereas conventional batteries degrade over time.

It is worth remembering that among the foremost challenges in the development of hybrids and electric cars are the size, weight, (toxicity) and cost of the current generation of batteries. In order to deliver sufficient capacity using today's technology, it is necessary to fit large batteries, which in turn exceedingly increases the car's weight. But when thinking of lightness one thinks about flying, and a solar plane that can flight at night seems to be sci-fi [18]. The Solar Impulse aircraft,

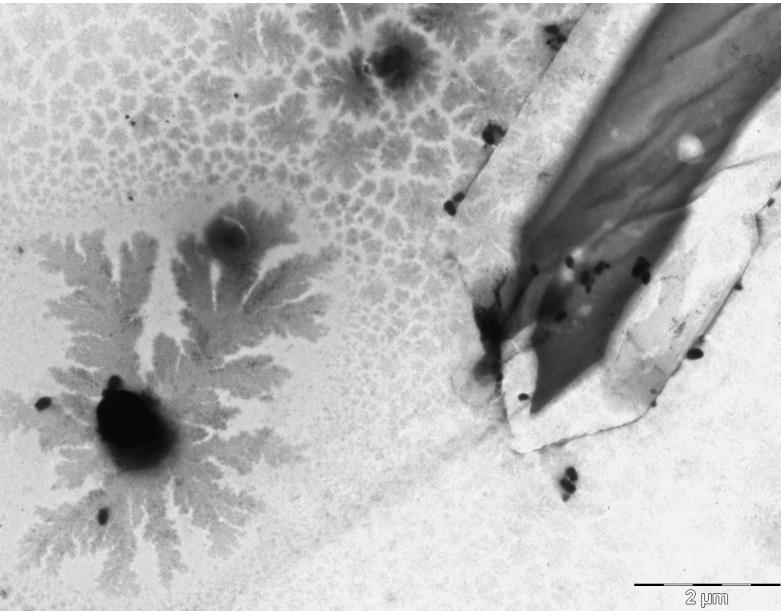
which is powered only by solar energy, triumphantly completed its first night flight. The ultralight aircraft was airborne for a total of 26 hours — from 7 am on July 7 until 9 am the following day (Central European Time) — before finally landing as planned at Payerne airbase in Switzerland. This aircraft is now officially the first manned aircraft capable of flying day and night without fuel, powered entirely by solar energy. The latest cutting-edge technology has been incorporated into this prototype airplane, which has the wingspan of a large airliner (63.40 meters) and the weight of a midsize car (1.600 kilograms). Some 12,000 solar cells cover its surface to run four electrical engines and store the solar energy for the night in 400 kilograms of lithium batteries. As was the case with instant soup and Teflon, which were developed as sidelines from the Apollo project, making things fly has important technological consequences. Thus, other potential derivatives from the Solar Impulse project include innovative adhesives, rigid polyurethane foams for paneling in the cockpit and engine, and extremely thin yet break-resistant polycarbonate films and sheets, in which carbon nanotubes and structural control at the nanoscale are paramount.

Expands But Does Not Break



Simple modifications may have large impacts. Nanowired batteries can hold 10 times the charge of existing Li-ion ones [19]. Researchers have found a way to use silicon nanowires to reinvent the rechargeable lithium-ion batteries that power laptops, iPods™, video cameras, cell phones, and countless other devices. Indeed, the greatly expanded storage capacity could also make Li-ion batteries attractive to electric-car manufacturers. The electrical-storage capacity of a Li-ion battery is limited by how much lithium can be held in the battery's anode, which is typically made of carbon. Silicon has a much higher capacity than carbon, but also has a drawback. Silicon placed in a battery swells as it absorbs positively charged lithium atoms during charging, then shrinks during use as the lithium is drawn out of the silicon. This expand/shrink cycle typically causes the silicon (often in the form of particles or a thin film) to pulverize, degrading the performance of the battery. A new battery gets around this problem with nanotechnology. The lithium is stored in a forest of tiny silicon nanowires, each with a diameter one-thousandth the thickness of a sheet of paper. The nanowires inflate to four times their normal size as they soak up lithium. But, unlike other silicon shapes, they do not fracture. It has been known for years that, when compared to the bulk, nanocrystals subjected to stress deform rather than break, in part due to the high energetic cost of a fracture (vacancies and dislocations) in such a tiny crystal domain.

As industries and consumers increasingly seek improved battery power sources, cutting-edge microscopy is providing an unprecedented perspective on how lithium-ion batteries function at the nano-

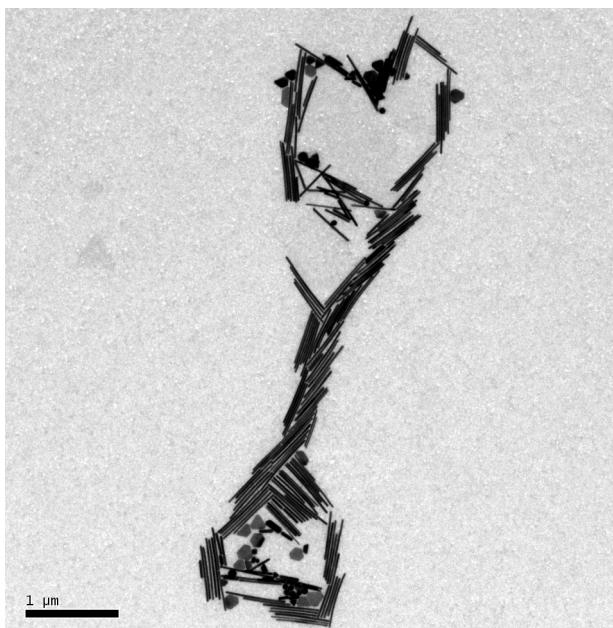


scale. Electrochemical strain microscopy examines the movement of lithium ions through a battery's cathode material in nanometer volumes. By measuring volume change, it is also possible to visualize how lithium ions flow through the material [20]. Conventional electrochemical techniques, which analyze electric current instead of strain, do not work on a nanoscale level because the electrochemical currents are too small to measure. Besides, very small changes at the nanometer level could have a huge impact at the device level. For example, size expansion and memory effects at the nanoscale will be better understood.

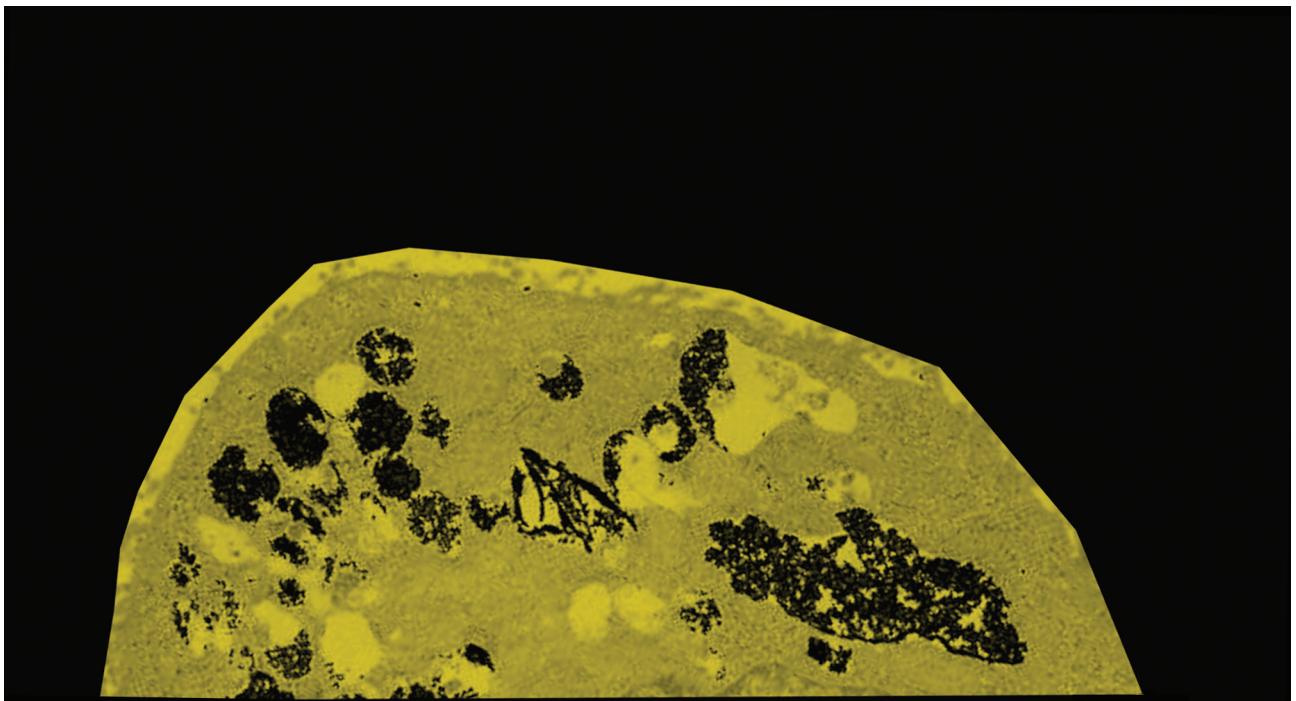
As we need to try and fail, bake and shake, laboratory models are very important. Thus, a bench-top version of the world's smallest battery with an anode consisting of a single nanowire, one seven-thousandth the thickness of the human hair, has been created [21]. This single nanobattery offers "a never-before-seen perspective" to improve batteries. These experiments enable us to study the charging and discharging of a battery in real time and with atomic resolution, thus enlarging our understanding of the fundamental mechanisms by which batteries work. Because nanowire-based materials in lithium-ion batteries offer the potential for significant improvements in power and energy density over bulk electrodes, more

stringent investigations of their operating properties should improve new generations of devices and commodities (as/if we need them).

Once again, the tin oxide nanowire rod employed in these studies nearly doubles in length during charging, which is far more than the increase in its diameter — a fact that helps to avoid short circuits and degradation that shorten battery life. The common belief of workers in this field has been that batteries swell across their diameter, not longitudinally. Researchers followed the progression of the lithium ions as they travel along the nanowire and create what researchers christened the "Medusa front" — an area where a high density of mobile dislocations causes the nanowire to bend and wiggle as the front progresses. This web of dislocations is caused by lithium penetration into the crystalline lattice. These observations proved that nanowires can sustain large stress (>10 GPa) induced by lithiation without breaking, which indicates that nanowires are very good candidates for battery electrodes.



We Need Much More Thought



As Alain Tourraine pointed out when receiving the Principe De Asturias price, todays crisis is not a financial crisis but an intellectual one. We need more, and better ideas. To understand and master anything we need to study, we can agree on that; in addition to study, we have to guess and speculate.

Firstly, to advance thoughts, one must do a lot of thinking. As discussed in “Could 135,000 Laptops Help Solve the Energy Challenge?”, [22] both the Jaguar (equivalent to 109.000 laptops) and Intrepid (26.000 laptops) supercomputers are being utilized as part of a research consortium to study and demonstrate a working prototype of a rechargeable lithium/air battery. The lithium/air battery can potentially store 10 times the energy of a lithium/ion battery of the same weight. This interest in massive computing finds echoes in the individuals who donate time on their personal computers for humanitarian projects by

registering on the World Community Grid, and installing a free, unobtrusive, and secure software program on their computers running either Linux, Microsoft Windows, or Mac OS. When idle or between keystrokes on a lightweight task, their PCs request data from World Community Grid’s server, which runs Berkeley Open Infrastructure for Network Computing (BOINC) software. This project has the intention of sharing idle computing time and thereby helping scientists to solve humanitarian challenges, many of them related, directly or indirectly, to energy.

There was also news on converting Brownian motion into work to suck energy from the thermal bath [23]. The molecular motors on which life depends on are driven by Brownian motion. In 1827, Robert Brown famously observed pollen grains dancing as if alive, under his microscope. At first he thought he might be observing the “elementary molecules of organic

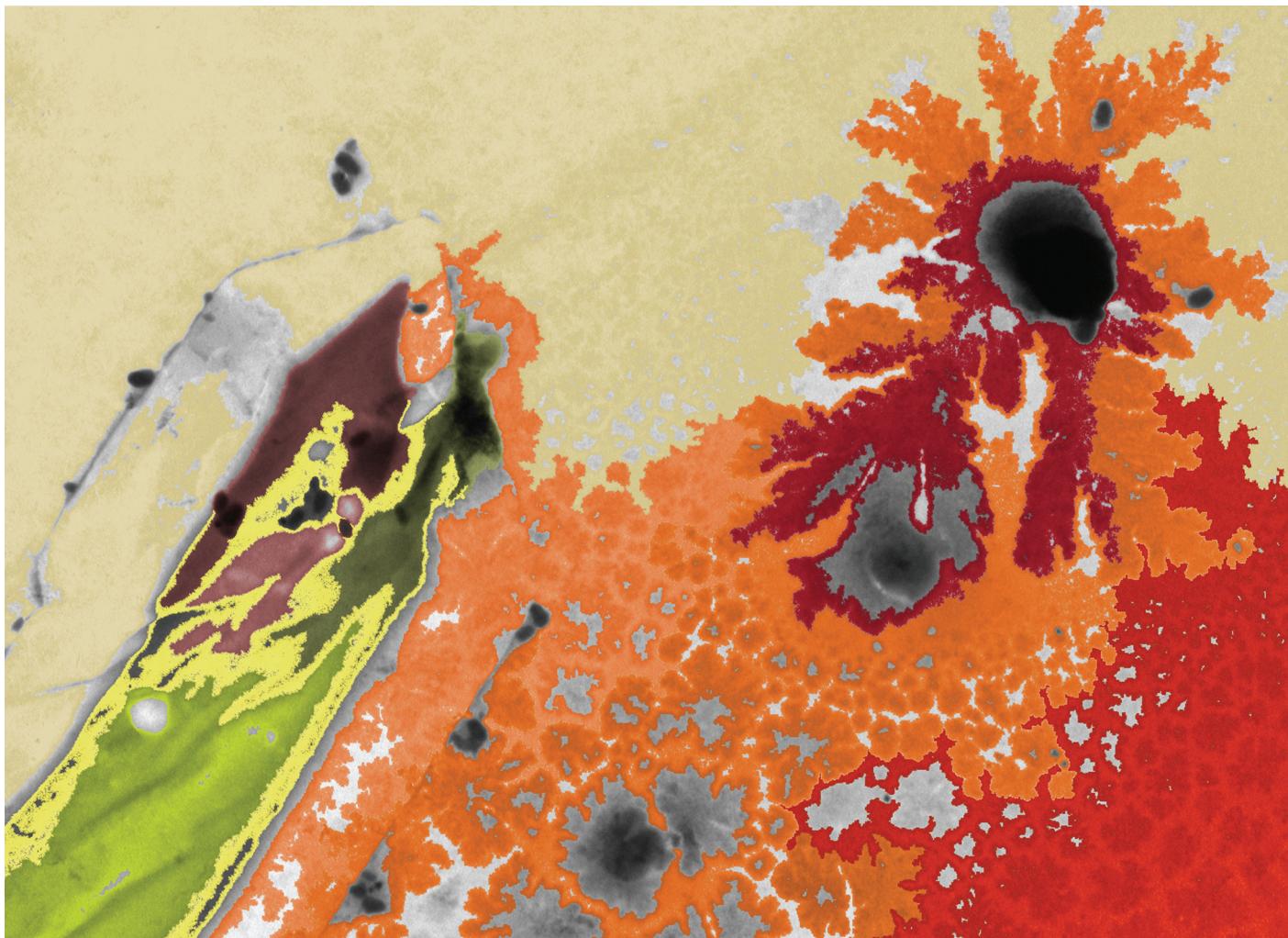


bodies" — the life force itself. However, when he repeated the experiment with fine clays, he observed the same. At the few-nanometer scale, molecular motors, such as those responsible for tensing and relaxing muscles, move in a particular manner: they propel themselves forwards despite — or thanks to — a continuous bombardment of randomly moving molecules in their surroundings. This random movement is called Brownian motion and a well-constructed nanoscale motor actually makes use of it to generate a directed movement (and therefore work). The device introduced by the physicist Marian Smoluchowski in 1912, as a *Gedankenexperiment*, is a classical example of such a motor. Obtaining work from a thermal bath may sound like a dream, but it is the way that mechanical work is done in molecular biology, how the messenger reaches the receptor or the tree pumps water to its highest leaf. This effect is probably restricted to devices that are about one order of magnitude larger than the size of the solvent molecules and close in density, and forces of femto-Newton have to fit in with complex machinery where random motion becomes profitable.

Tiny energy for tiny devices is a very se-

ductive idea. Thus, as you can not plug a nanosensor or nanodevice into a power grid if it has to travel, scan, and report, we need self-powered nanodevices. By combining a new generation of piezoelectric nanogenerators with two types of nanowire sensors, researchers have created what are believed to be the first self-powered nanometer-scale sensing devices that draw power from the conversion of mechanical energy [24]. The new devices can measure the pH value of liquids or detect the presence of ultraviolet light using electrical current produced from mechanical energy in the environment. For conversion of mechanical energy into electricity, piezos, such as devices in shoes to feed mobile phones, already exist; with nano dimensions, the density of units increases thanks to miniaturization and the performance increases due to increased elasticity. The new generator and nano-scale sensors open up new possibilities for very small sensing devices that can operate without batteries, which are powered by mechanical energy harvested from the environment. Energy sources could include the motion of tides, sonic waves, mechanical vibration, the flapping of a flag in the wind, pressure from shoes of a hiker, or the movement of clothing.

Sweet Electrons



Finally, one of the sweetest ideas presented was “A New Solar Cell Technology based on Doughnuts and Tea”. It turns out that these delicious little things contain everything we need to make a simple solar cell [25]. The resulting power may be small, but it could charge a mobile phone or sensor and it reminds us how close and accessible nature is, through the knowledge that we can produce electricity from sun in the kitchen. In search of cheap efficient solar cells made from raw, available materials, the authors presented how to get solar cells from powdered doughnuts (as a source of the semiconductor TiO_2)

and some passion tea (a dye) full of anthocyanins that color the TiO_2 and shift the TiO_2 absorbance from the UV to the visible range and produce electricity when exposed to the Sun.

Where Is the White Rabbit?

Later in the year, the Friends of the Earth (FOE) released a document entitled “Nanotechnology, climate and energy: Overheated promises and hot air?” [26]

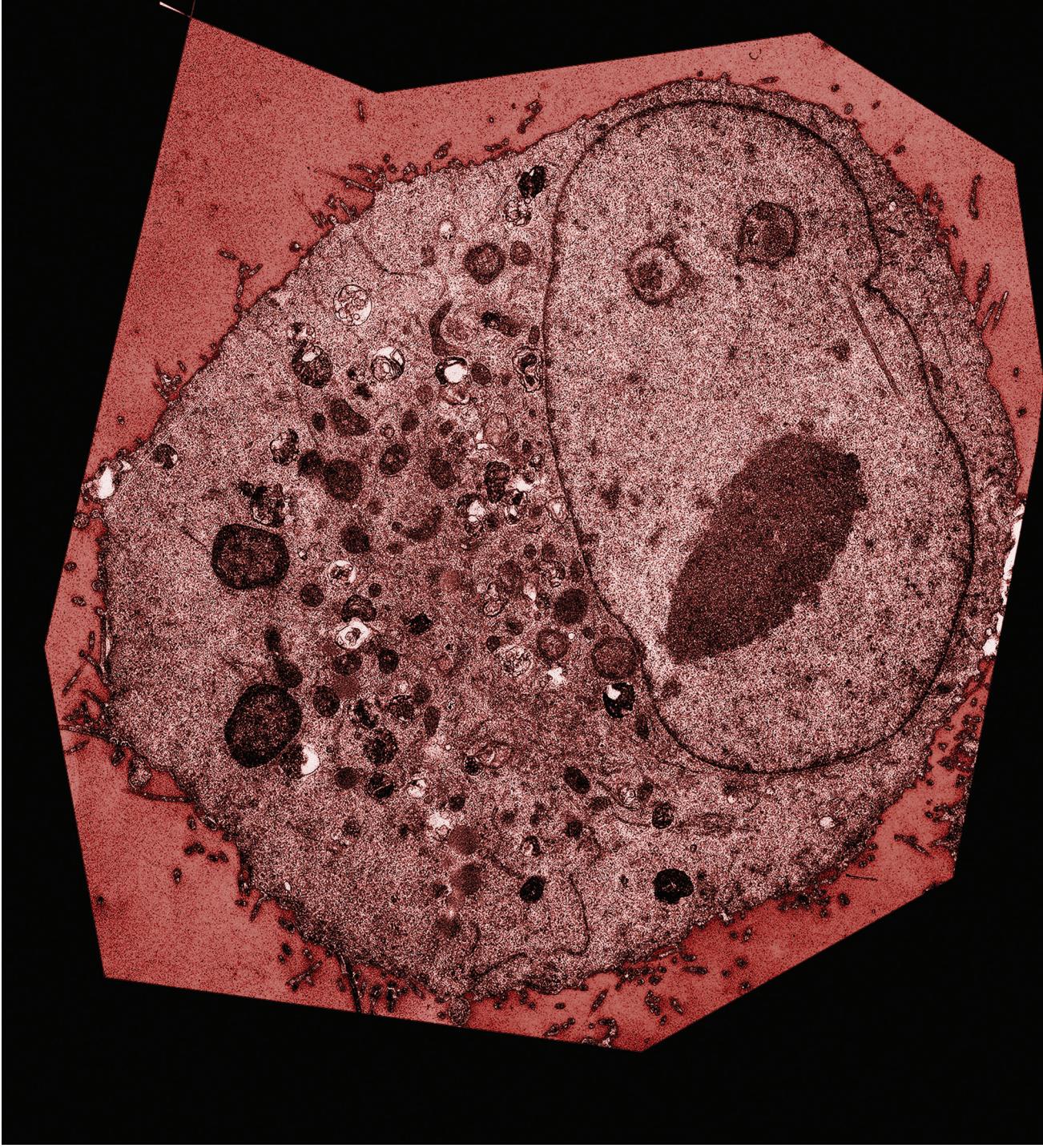
In this document, FOE say: “despite claims that nanotechnology can limit climate change and promote energy efficiency, we’ve found that the use of nanotechnology actually comes at a large environmental cost, people to continue with ‘business as usual’ and avoid serious improvements in energy efficiency and behavioral changes”. Whoa! Please, let us do this right. I think they are going too fast, and going too fast will turn work into power and consequently increase energy consumption. Slow down; urge is not sustainable. Recently we published a little paper about our experience in a European project on Nanotoxicology, where some company was already selling products with bioactive nanoparticles while scientists were still wondering how to deal with them safely [27]. This is then not precisely

a problem of science and knowledge (to me it is a problem of ignorance, we should better understand the world at is molecular and nanometric level to promote more responsible technologies). It is a problem of a social kind of hysteria. The “when do we want it? — Now!” concept does not fully apply to natural processes, civilization building, or responsible technological development. In fact, business is, as usual, a social cultural problem and not really scientific. To deny and obscure science may be tempting to some who feel that humans are not up to the challenge, but such obscuring attitudes have never led to any good.

The report also highlights how nanotechnology is primarily used in products that do not provide energy savings, such as clothing, cosmetics, and sporting goods. This is true, but it is also “noise”, which should not distract us too much. To some extent it could be as simple as allowing regulation of technology by applying common-sense precautionary principles over a reasonable period of time, while more useful applications are being developed beyond colloidal gold for the soul or biocide nanoparticles as deodorants. Senseless panic and euphoria often parasitize discovery and parasitizing is a natural fingerprint of molecular biology.

Additionally, nanotechnology is not by its nature expensive and energy consuming, though some aspects of its study are. However, in producing nanotechnology, it depends if you use a laser beam to sculpt out a nanometric figure in a high vacuum chamber or if you add a mixture of salts and surfactants in a controlled manner at room temperature to produce amazing





nanoparticles at incredibly low raw-material prices.

In response to the FOE report, 350.org founder Bill McKibben said, "Very few people have looked beyond the shiny promise of nanotechnology to try and understand how this far-reaching new technique is actually developing. This report is an excellent glimpse inside, and it offers a judicious and balanced account of a subject we need very much to be thinking about." I am not sure about what people

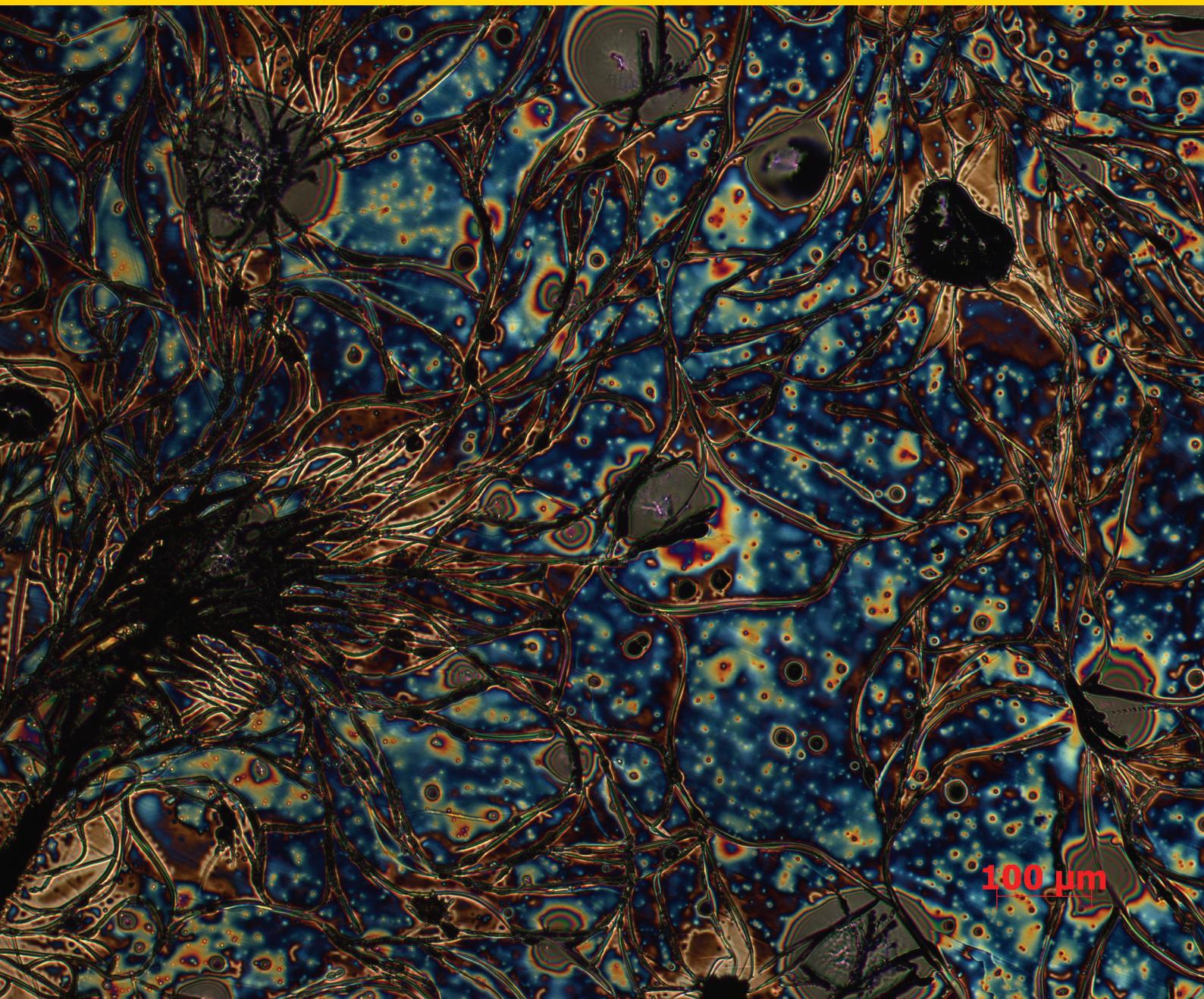
think and how far they look, but we honestly hope Nanowiki will help people to reflect upon all those important subjects; not just the lay people, but also scientists and all other citizens.

Víctor Puntes
and the Inorganic Nanoparticles Group-
January 2011

The province of scientifically determined fact has been enormously extended; theoretical knowledge has become vastly more profound in every department of science. But the assimilative power of the human intellect is and remains strictly limited. Hence it was inevitable that the activity of the individual investigator should be confined to a smaller and smaller section of human knowledge. Worse still, as a result of this specialization, it is becoming increasingly difficult for even a rough general

grasp of science as a whole, without which the true spirit of research is inevitably handicapped, to keep pace with progress. A situation is developing similar to the one symbolically represented in the Bible by the story of the Tower of Babel. Every serious scientific worker is painfully conscious of this involuntary relegation to an ever-narrowing sphere of knowledge, which is threatening to deprive the investigator of his broad horizon and degrade him to the level of a mechanic.

In Honour of Arnold Berliner's Seventieth Birthday, Albert Einstein

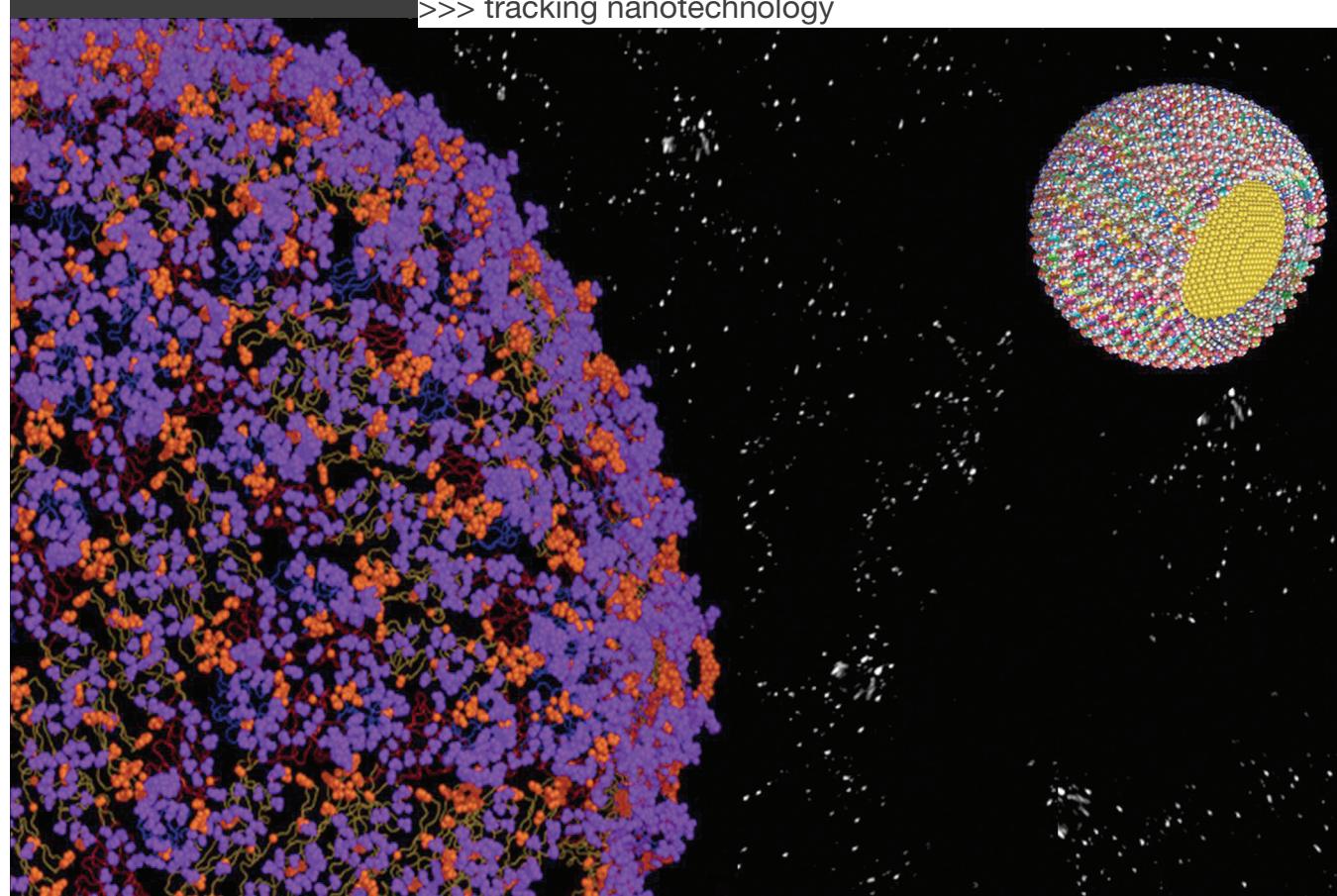


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>>> tracking nanotechnology



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Scientists as Artists in Nano Science and Technology

Roger Malina, February 15, 2010
tags: art + Roger Malina + leonardo/isast

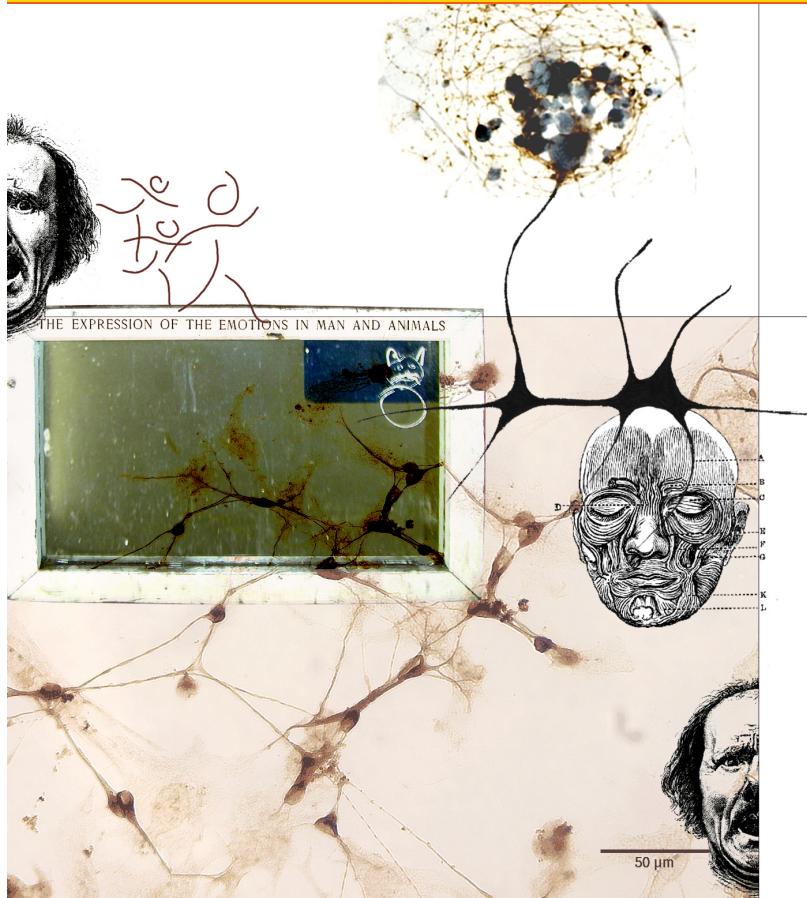


Image: 'mirror your neurons expressions' by Joan Escofet for context weblog

In looking at the interaction of nano science and the arts it is interesting to look at the interest of scientists in the arts. These fall into two broad categories:

- a) Scientists who have engaged in artistic practice during their scientific career, and this was important to their creativity.
- b) Scientists who have collaborated with artists to create art works and this influenced their research practice, as well as creating art work exhibited professionally.

In the first category, Leonardo Co Editor Robert Root Bernstein wrote a note about Nobel prize winning chemist Dorothy Crowfoot Hodgkin.

Dodgkin was a talented amateur artist and botanist who became a world authority on Sudanese flowers, ancient textiles and weaving techniques. She also became an expert on mosaics.

DOROTHY CROWFOOT HODGKIN: STRUCTURE AS ART
June 2007, Vol. 40, No. 3, Pages 259-261
© 2007 Massachusetts Institute of Technology
Robert Root-Bernstein: Art Science the Essential Connection
Department of Physiology, Michigan State University, East Lansing, MI 48824 U.S.A.
E-mail: rootbern@msu.edu

Hodgkin credits her drawing practice as being crucial to her development ideas on symmetry groups and chemical structure. At the end her life she drew many drawings.

"What she finished instead were stunning images of natural structures too small for the naked eye to perceive—surely a form of art as creative and inspiring as the mosaics, Celtic knots and architectural innovations she recorded in her earlier years."

With recent work on mirror neurons, we are developing better ideas of how the human mind constructs mental models, and often this involves kinesthetic mirroring. Drawing and other artistic practice can be strategies for scientific creativity and innovation.

Derrick de Kerchove in the recent YASMIN discussion on "Simulation" pointed out that it will also force us to art practice in a new way: "Though still controversial, if the theory (mirror neurons) turns out to be verified, it may have consequences for the study of media, of performing arts and of the growing practice of simulation in general. The acting profession from ancient Greek theatre to television, cinema and virtual reality could be no more and no less than a biological strategy to introduce new and complex human experience and behavior in society. It would go at some length to explain the manner by which the spectator accesses emotions that are quite literally projected into him or her by the performance."

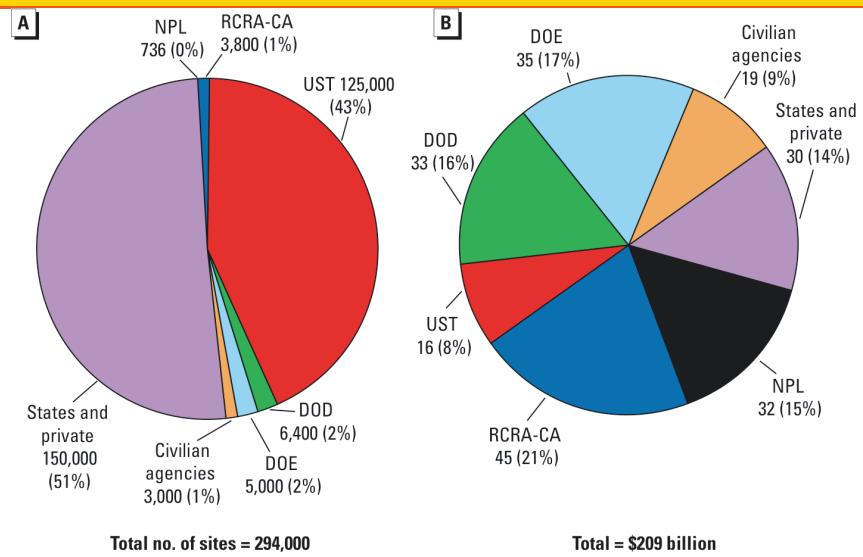
As we look at the way that nano scientists and nano technologists are involved in the arts we need to understand the retro active of their art making on themselves and their creativity, as well as the way the art works produced allow viewers to access new domains of the natural world. They in effect are developing new forms of sensuality for sensory awareness mediated by scientific instruments. **Source:** Via Leonardo/ISAST cooperation with NanoWiki.

Contaminated site nanoremediation

Josep Saldaña, August 3, 2009
tags: nanoremediation + waste + nanotoxicology

While industrial sectors involving semiconductors, memory and storage technologies, display, optical and photonic technologies, energy, biomedical, and health sectors produce the most nanomaterial-containing products, nanotechnology is also used as an environmental technology to protect the environment through pollution prevention, treatment, and cleanup. This paper focuses on environmental cleanup and provides readers with a background and overview of current practice, research findings, societal issues, potential environment, health, and safety implications, and future directions for nanoremediation. We do not present an exhaustive review of chemistry/engineering methods of the technology but rather an introduction and summary of the application of nanotechnology in remediation. Nanoscale zero valent iron is discussed in more detail. We searched Web of Science for research studies and accessed recent U.S. Environmental Protection Agency (EPA) and other publicly available reports that addressed the applications and implications associated with nanoremediation techniques. We also conducted personal interviews with practitioners about specific site remediations. Information from 45 sites, a representative portion of the total projects underway, was aggregated to show nanomaterials used, type of pollutants cleaned up, and organization responsible for the site.

Nanoremediation has the potential not only to reduce the overall costs of cleaning up large scale contaminated sites, but it also can reduce cleanup time, eliminate the need for treatment and disposal of contaminated soil, reduce some contaminant concentrations to near zero—all in situ. Proper evaluation of nanoremediation, particularly full-scale ecosystem wide studies, needs to be conducted to prevent any potential adverse environmental impacts.



Estimated number (%) of U.S. hazardous waste sites (A) and estimated cleanup costs [billions US\$ (percent of total)] for 2004–2033 (B). UST, underground storage tanks. Adapted from U.S. EPA (2004).



Map of remediation sites listed in Supplemental Material, Table 2. Project on Emerging Nanotechnologies 2009.

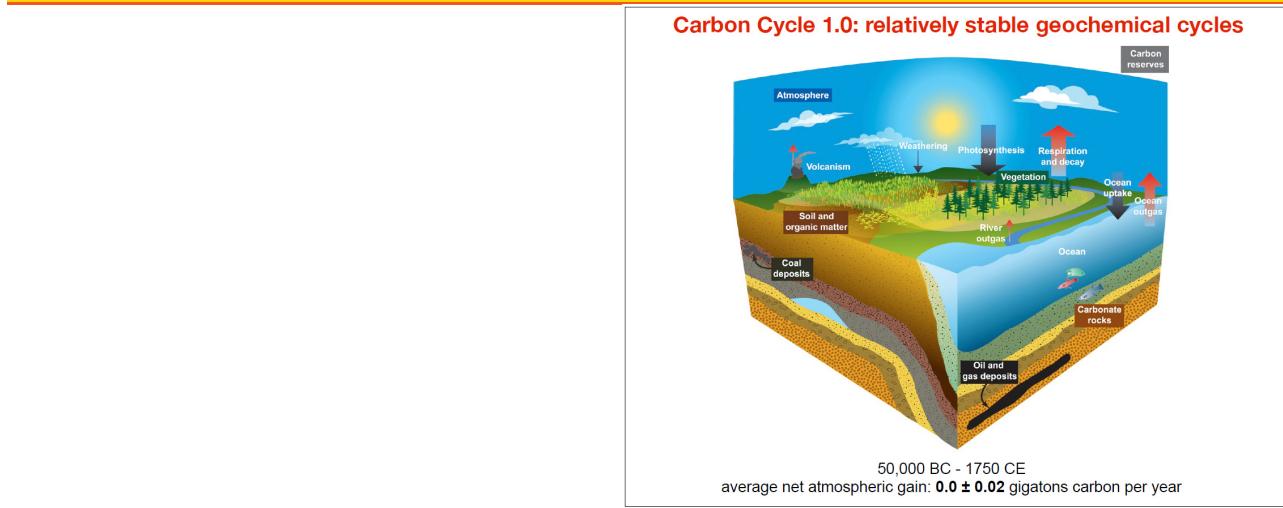
Source: From **Nanotechnology and In situ Remediation: A review of the benefits and potential risks** by Barbara Karn, Todd Kuiken, Martha Otto. This article has been reviewed by the U.S. Environmental Protection Agency and approved for publication.

The Project on Emerging Nanotechnologies has produced a map - Nanoremediation map - showing the location of sites at which nanotech-

nology has been used as a remediation technology and providing some information about each site.

Carbon Cycle 2.0

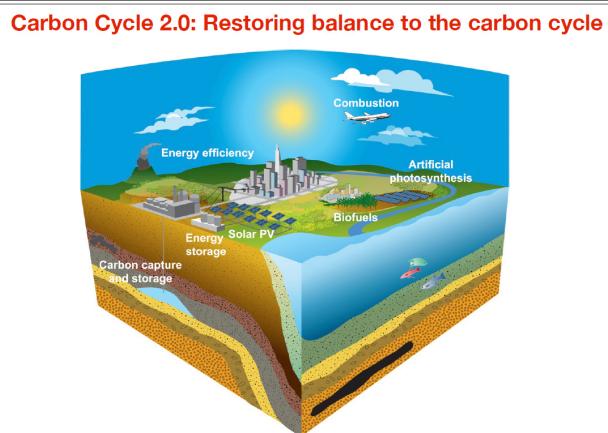
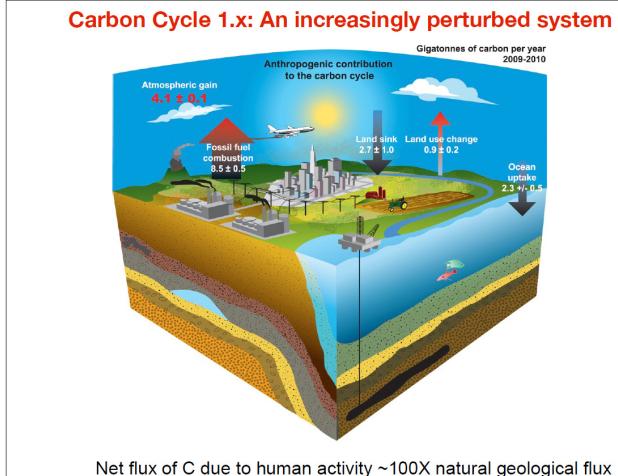
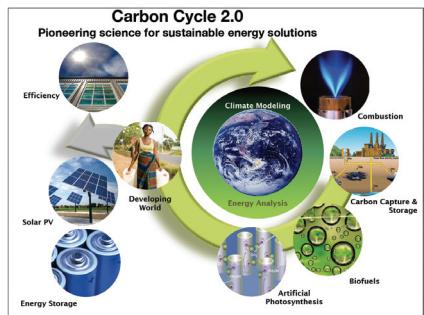
josep saldaña, October 25, 2010
tags: energy + climate



Earth's carbon cycle is overburdened. We emit more carbon into the atmosphere than natural processes are able to remove - an imbalance with negative consequences. Carbon Cycle 2.0 is a Berkeley Lab initiative to provide the science needed to restore this balance by integrating the Lab's diverse research activities and delivering creative solutions toward a carbon-neutral energy future.

Carbon Cycle 2.0 means collaboration 2.0: tackling one of the greatest challenges facing the nation and world will require an urgent and more creative take on the kind of cross-disciplinary problem solving needed to bridge the gap between basic and applied research. In the spirit of what made Berkeley Lab great, the entire Lab community must take initiative and engage on CC2.0 for it to be a success.

Source: Berkeley Lab - Carbon Cycle 2.0



Balance can be restored while allowing for growth in population and wellbeing

Frames from Director Alivisatos's Climate Change Presentation.
January 2011

Crystal Sponges to Capture CO₂

josép saldaña, July 18, 2010
tags: nanomaterial + climate + energy

Chemists from UCLA and South Korea report the “ultimate porosity of a nano-material,” achieving world records for both porosity and carbon dioxide storage capacity in an important class of materials known as MOFs, or metal-organic frameworks.

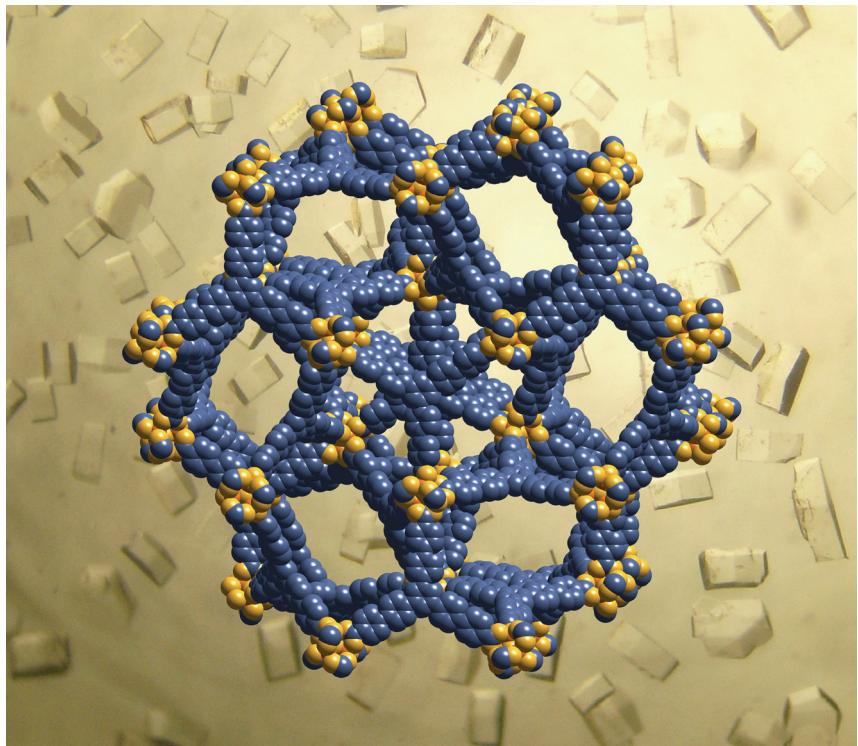
MOFs, sometimes described as crystal sponges, have pores — openings on the nanoscale which can store gases that are usually difficult to store and transport. Porosity is crucial for compacting large amounts of gases into small volumes and is an essential property for capturing carbon dioxide.

The research could lead to cleaner energy and the ability to capture heat-trapping carbon dioxide emissions before they reach the atmosphere and contribute to global warming, rising sea levels and the increased acidity of oceans.

“We are reporting the ultimate porosity of a nano-material; we believe this to be the upper limit or very near the upper limit for porosity in materials,” said the paper’s senior author, Omar Yaghi, a UCLA professor of chemistry and biochemistry and a member of both the California NanoSystems Institute (CNSI) at UCLA and the UCLA-Department of Energy Institute of Genomics and Proteomics.

With lead author Hiroyasu (Hiro) Furukawa, co-author Jaheon Kim and colleagues, Yaghi reports on two materials that not only break the porosity record, but do so by an extremely large margin. The materials are MOF-200, made at UCLA by Furukawa, a postdoctoral scholar in Yaghi’s laboratory, and MOF-210, made at Seoul’s Soongsil University in South Korea by Kim, a chemistry professor and former graduate student in Yaghi’s laboratory, and colleagues.

Invented by Yaghi the early 1990s, MOFs are like scaffolds



Crystal structure of MOF-200, in UCLA's blue and gold. Atom colors: UCLA blue = carbon, UCLA gold = oxygen, orange = zinc. Optical image of MOF-200 crystals. (Credit: UCLA Department of Chemistry and Biochemistry; UCLA-Department of Energy Institute of Genomics and Proteomics).

Made of linked rods, with nano-scale pores that are the right size to trap carbon dioxide. The components of MOFs can be changed nearly at will, and Yaghi’s laboratory has made several hundred MOFs, with a variety of properties and structures.

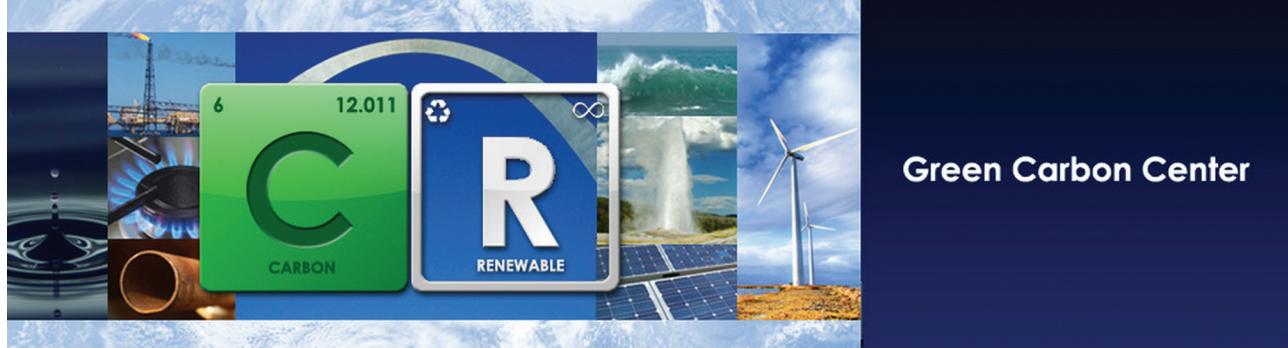
Since 1999, MOFs have held the record for having the highest porosity of any material. MOFs can be made from low-cost ingredients, such as zinc oxide, a common ingredient in sunscreen, and terephthalate, which is found in plastic soda bottles. **If I take a gram of MOF-200 and unravel it, it will cover many football fields,** and that is the space you have for gases to assemble,” Yaghi said. “It’s like magic. Forty tons of MOFs

is equal to the entire surface area of California.”

Yaghi, Furukawa and Kim also report a record for carbon dioxide storage capacity. **MOF-200 and MOF-210 take up the highest amount of hydrogen, methane and carbon dioxide**, by weight, ever achieved. **Source:** World records by UCLA chemists, Korean colleagues enhance ability to capture CO₂ by Stuart Wolpert. This work is detailed in the paper Ultra-High Porosity in Metal-Organic Frameworks by Hiroyasu Furukawa, Nakeun Ko, Yong Bok Go, Naoki Aratani, Sang Beom Choi, Eunwoo Choi, A. Özgür Yazaydin, Randall Q. Snurr, Michael O’Keeffe, Jaheon Kim, Omar M. Yaghi.

Green Carbon Center

josep saldaña, October 26, 2010
tags: energy + climate



Rice University has created a Green Carbon Center to bring the benefits offered by oil, gas, coal, wind, solar, geothermal, biomass and other energy sources together in a way that will not only help ensure the world's energy future but also provide a means to recycle carbon dioxide into useful products.

Whether or not one believes in anthropogenic climate change, the fact is humans are throwing away a potentially valuable resource with every ton of carbon dioxide released into the atmosphere, said James Tour, Rice's T.T. and W.F. Chao Chair in Chemistry as well as a professor of mechanical engineering and materials science and of computer science. Far from being a villain in the global warming debate, carbon will be a boon if the world can learn to use it well, he said. "The key is to turn carbon dioxide into a useful material so it's no longer waste," he said. "We want the center to partner with energy companies — including oil, natural gas and coal — to make carbon a profitable resource."

A number of strategies are detailed in a paper. Tour said the paper presents a taste of what Rice's new center intends to be: **a think tank for ideas about the future of energy with a focus on green carbon and the technological know-how to back it up.** As part of Rice's Richard E. Smalley Institute for Nanoscale Science and Technology, the Green Carbon Center will draw upon the combined knowledge of the university's nanotechnology experts, for whom the development of clean and plentiful energy is a priority.

"Eighty-five percent of our country's energy comes from fossil fuels, and Houston is the world capital of the industry that makes and produces and transports those fossil fuels to all of us," Colvin said. "So we are in a unique position as the leading university in Texas to transform that industry, to develop it in a green way, to make it sustainable and to teach people that just because it's carbon doesn't mean it has an environmental consequence, but it can in fact help us transition to a renewable energy economy of the future."

Source: From Green Carbon Center takes all-inclusive view of energy. Rice University think tank will strategize on environmentally sound policies on oil, gas, coal by Mike Williams. A number of strategies are detailed in the paper **"Green carbon as a bridge to renewable energy"** by James M. Tour, Carter Kittrell & Vicki L. Colvin.

Abstract

A green use of carbon-based resources that minimizes the environmental impact of carbon fuels could allow a smooth transition from fossil fuels to a sustainable energy economy.

Carbon-based resources (coal, natural gas and oil) give us most of the world's energy today, but the energy economy of the future must necessarily be far more diverse. Energy generation through solar, wind and geothermal means is developing now, but not fast enough to meet our expanding global energy needs.

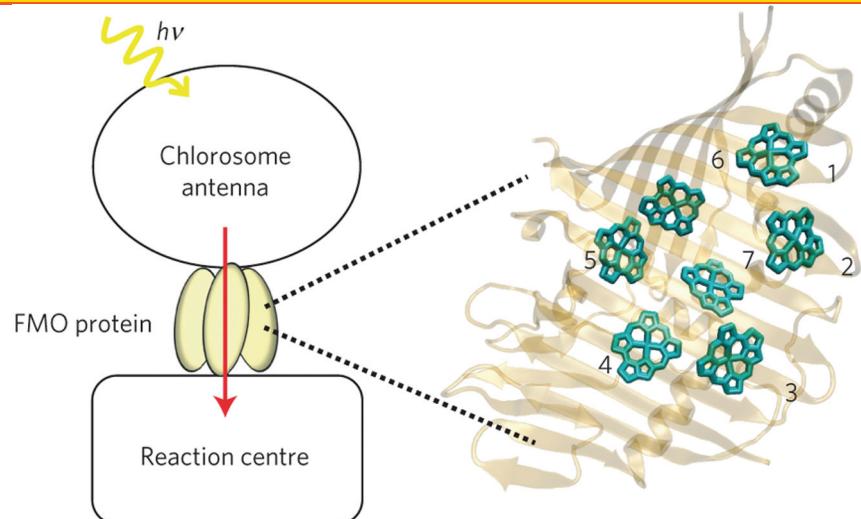
Unraveling the mysteries of photosynthesis

Josep Saldaña, May 12, 2010
tags: milestone + photosynthesis + energy + nanophotonics

The future of clean green solar power may well hinge on scientists being able to unravel the mysteries of photosynthesis, the process by which green plants convert sunlight into electrochemical energy. To this end, researchers with the U.S. Department of Energy (DOE)'s Lawrence Berkeley National Laboratory (Berkeley Lab) and the University of California (UC), Berkeley have recorded **the first observation and characterization of a critical physical phenomenon behind photosynthesis known as quantum entanglement.**

Previous experiments led by Graham Fleming, a physical chemist holding joint appointments with Berkeley Lab and UC Berkeley, pointed to quantum mechanical effects as the key to the ability of green plants, through photosynthesis, to almost instantaneously transfer solar energy from molecules in light harvesting complexes to molecules in electrochemical reaction centers. Now a new collaborative team that includes Fleming have identified entanglement as a natural feature of these quantum effects. When two quantum-sized particles, for example a pair of electrons, are "entangled," any change to one will be instantly reflected in the other, no matter how far apart they might be. Though physically separated, the two particles act as a single entity.

"This is the first study to show that entanglement, perhaps the most distinctive property of quantum mechanical systems, is present across an entire light harvesting complex," says Mohan Sarovar, a post-doctoral researcher under UC Berkeley chemistry professor Birgitta Whaley at the Berkeley Center for Quantum Information and Computation. "While there have been prior investigations of entanglement in toy systems that were motivated by biology, this is the first instance in which entanglement has been examined and quantified in a real biological



The schematic on the left shows the absorption of light by a light harvesting complex and the transport of the resulting excitation energy to the reaction center through the FMO protein. On the right is a monomer of the FMO protein, showing its orientation relative to the antenna and the reaction center. The numbers label FMO's seven pigment molecules.
Image by Mohan Sarovar and Akihito Ishizaki.

system."The results of this study hold implications not only for the development of artificial photosynthesis systems as a renewable non-polluting source of electrical energy, but also for the future development of quantum-based technologies in areas such as computing – a quantum computer could perform certain operations thousands of times faster than any conventional computer.

What may prove to be this study's most significant revelation is that contrary to the popular scientific notion that entanglement is a fragile and exotic property, difficult to engineer and maintain, the Berkeley researchers have demonstrated that **entanglement can exist and persist in the chaotic chemical complexity of a biological system.** "We present strong evidence for quantum entanglement in noisy non-equilibrium systems at high temperatures by determining the timescales and temperatures for which entanglement is observable in a protein structure that is central to photosynthesis in certain bacteria,"

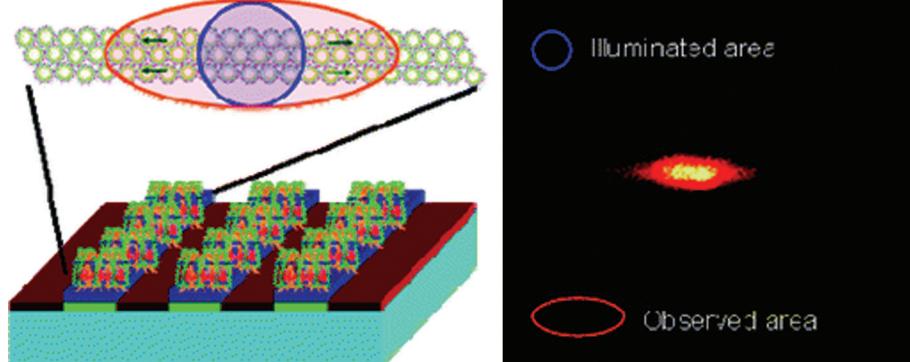
Sarovar says.

Green plants and certain bacteria are able to transfer the energy harvested from sunlight through a network of light harvesting pigment-protein complexes and into reaction centers with nearly 100-percent efficiency. Speed is the key – the transfer of the solar energy takes place so fast that little energy is wasted as heat. In 2007, Fleming and his research group reported the first direct evidence that this essentially instantaneous energy transfer was made possible by a remarkably long-lived, wavelike electronic quantum coherence.

Source: From **Untangling the Quantum Entanglement Behind Photosynthesis: Berkeley scientists shine new light on green plant secrets** by Lynn Yarris. This work is detailed in the paper **Quantum entanglement in photosynthetic light-harvesting complexes** by Mohan Sarovar, Akihito Ishizaki, Graham R. Fleming & K. Birgitta Whaley.

'Molecular Glass Fibre'

josep saldaña, July 11, 2010
tags: photosynthesis + nanophotonics + energy



Here we report the first observation of long-range transport of excitation energy within a biomimetic molecular nanoarray constructed from LH2 antenna complexes from Rhodobacter sphaeroides.

Nanotechnologists have discovered that **the photosynthesis system of bacteria can be used to transport light over relatively long distances. They have developed a type of 'molecular glass fibre'**, a thousand times thinner than a human hair.

All plants and some bacteria use photosynthesis to store energy from the sun. Researchers from the MESA+ Institute for Nanotechnology of the University of Twente have now discovered how parts of the photosynthesis system of bacteria can be used to transport light. In their experiments the researchers used isolated proteins from the so-called Light Harvesting Complex (LHC). These proteins transport the sunlight in the cells of plants and bacteria to a place in the cell where the solar energy is stored. The researchers built a type of 'molecular glass fibre' from the LHC proteins that is a thousand times thinner than a human hair.

In the experiment the researchers fastened the proteins onto a fixed background. They positioned them in a line, and in this way formed a thread. They then shone laser light to

one point in the thread, and observed where the light went to. The line with the LHC proteins did not only transport the light, but transported it over much longer distances than the researchers had initially expected. Distances of around 50 nanometres are normally bridged in the bacteria from which the LHC proteins were isolated. In the researchers' experiments the light covered distances at least thirty times greater.

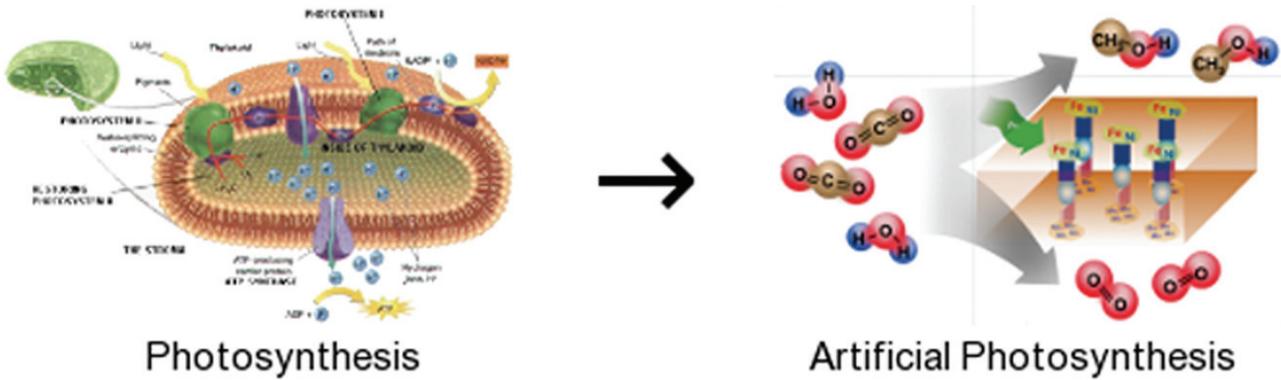
According to Cees Otto, one of the researchers involved, we can learn a lot from nature in experiments such as this. "The LHC proteins are the building blocks that nature gives us, and using them **we can learn more about natural processes such as the transport of light in photosynthesis**. When we understand how nature works, we can then imitate it. In time we will be able to use this principle in, for example, solar panels."

The research was carried out in partnership with the University of Sheffield, and fully financed by NanoNed. **Source:** MESA+/University of Twente nanotechnologists create 'molecular glass fibres'. This work is detailed in the paper Long-Range Energy

Propagation in Nanometre Arrays of Light Harvesting Antenna Complexes by Maryana Escalante, Aufried Lenferink, Yiping Zhao, Niels Tas, Jurriaan Huskens, Neil Hunter, Vinod Subramaniam and Cees Otto. "Here we report the first observation of long-range transport of excitation energy within a biomimetic molecular nanoarray constructed from LH2 antenna complexes from Rhodobacter sphaeroides."

Energy Innovation Hub

josép saldaña, September 17, 2010
tags: photosynthesis + energy + national initiatives + video



As part of a broad effort to achieve breakthrough innovations in energy production, U.S. Deputy Secretary of Energy Daniel Poneman announced an award of up to \$122 million over five years to a multidisciplinary team of top scientists to **establish an Energy Innovation Hub aimed at developing revolutionary methods to generate fuels directly from sunlight**.

The Joint Center for Artificial Photosynthesis (JCAP), to be led by the California Institute of Technology (Cal Tech) in partnership with the U.S. Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab), will bring together leading researchers in an **ambitious effort aimed at simulating nature's photosynthetic apparatus for practical energy production**. The goal of the Hub is to develop an integrated solar energy-to-chemical fuel conversion system and move this system from the bench-top discovery phase to a scale where it can be commercialized.

JCAP research will be directed at the discovery of the functional components necessary to assemble a complete artificial photosynthetic system: light absorbers, catalysts, molecular linkers, and separation membranes. The Hub will then integrate those components into an operational solar fuel system and develop scale-up

strategies to **move from the laboratory toward commercial viability**.

The ultimate objective is to drive the field of solar fuels from fundamental research, where it has resided for decades, into applied research and technology development, thereby setting the stage for the creation of a direct solar fuels industry.

The Hub will be directed by Nathan S. Lewis, Cal Tech. Other members of the Hub leadership team include: Bruce Brunschwig (Cal Tech), Peidong Yang (UC Berkeley/Berkeley Lab), and Harry Atwater (Cal Tech). In addition to the major partners, Cal Tech and Berkeley Lab, other participating institutions include SLAC National Accelerator Laboratory, Stanford, California; the University of California, Berkeley; the University of California, Santa Barbara; the University of California, Irvine; and the University of California, San Diego.

Learn more information on the Hubs.

Source: From **Caltech-led Team Gets up to \$122 Million for Energy Innovation Hub**. Caltech will partner with Lawrence Berkeley Nat. Lab. and other CA institutions to develop method to produce fuels from sunlight

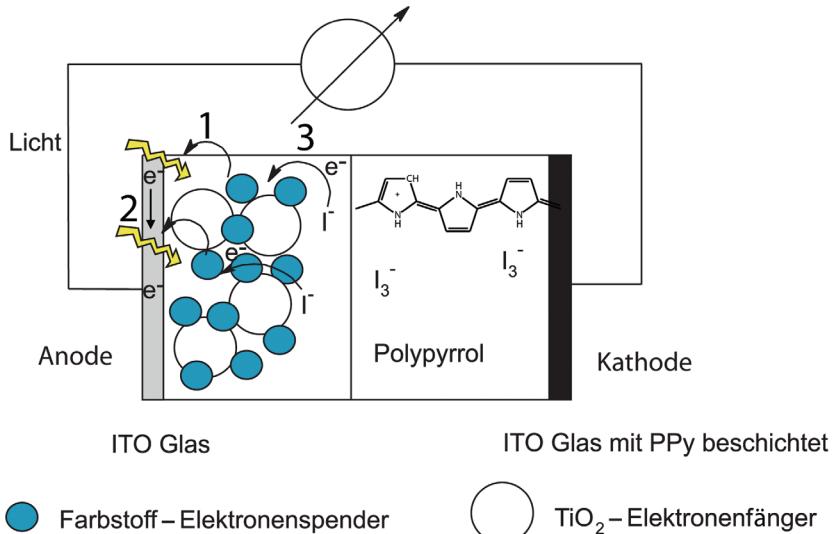
In response to the announcement, Berkeley Lab director Paul Alivisatos, an authority on nanocrystals for solar energy applications and founder of the

Helios: Solar Energy Research Center, said, "In order to replace fossil fuels, we need to get a lot more proficient at harvesting sunlight and converting it into forms of energy that can be used for transportation and other human needs. **Nature provides a model solution to this problem through photosynthesis**. We want to emulate this process but do it with artificial materials that could be much more efficient and use much less land. The ultimate goal would be to deploy an artificial photosynthetic system across a large geographical area, at a level of efficiency that could provide the United States with a significant alternative fuel source."

Source: From Berkeley Lab Part of California Team to Receive up to \$122 million for Energy Innovation Hub to Develop Method to Produce Fuels from Sunlight.

Millennium Prize for Grätzel cells

josep saldaña, June 14, 2010
tags: milestone + energy + nanoparticles + photosynthesis



Principle of the Grätzel cell
by Sebastian Spohn, Dietmar Dr. Scherr

The 2010 Millennium Prize Laureate Michael Grätzel is the father of third generation dye-sensitized solar cells. Grätzel cells, which promise electricity-generating windows and low-cost solar panels, have just made their debut in consumer products.

"For his invention and development of dye-sensitized solar cells, known as 'Grätzel cells'. The excellent price/performance ratio of these novel devices gives them major potential as significant contributor to the diverse portfolio of future energy technologies. Grätzel cells are likely to have an important role in low-cost, large-scale solutions for renewable energy. Besides photovoltaics, the concepts of Grätzel cells can also be applied in batteries and hydrogen production, all important components of future energy needs." - International Selection Committee

One of mankind's greatest challenges is to find ways to replace the diminishing fossil fuel supply. The most obvious energy source is the sun, origin of almost all the energy found on Earth.

The surface of the Earth receives solar radiation energy at an average of 81,000 terawatt – exceeding the whole global energy demand by a factor of 5,000. Yet, we are still figuring out a cost-effective way of harnessing it.

Solar cells, converting energy from the sun into electricity, were first used in the 1950s to power orbiting satellites and other spacecraft. Applied to power generation on Earth, the price does matter. Selected silicon based technology was – and still is – expensive, even if the cost of photovoltaics has declined steadily since the first solar cells were manufactured.

Grätzel's innovation, the dye solar cell (DSC), is a **third generation photovoltaic technology**. The technology often described as '**artificial photosynthesis**' is a promising alternative to standard silicon photovoltaics. It is made of low-cost materials and does not need an elaborate apparatus to manufacture. Though DSC cells are still in relatively early stages of development, they show great promise as an inexpensive

alternative to costly silicon solar cells and an attractive candidate for a new renewable energy source.

In the 1980s Grätzel was working doing basic research on nanotechnology. **They were the first to make nanoparticles from titanium oxide.** The properties of the new material were examined in many ways. "That was a fundamental study, just driven by our curiosity. Nobody had done it before. However this experiments provided important insight in the sensitization process that formed the scientific basis for the subsequent realization of dye sensitized solar cells."

Source: Millennium Prize - PROFESSOR MICHAEL GRÄTZEL: DEVELOPMENT OF DYE-SENSITIZED SOLAR CELLS. The original landmark paper presenting an entirely new paradigm in photovoltaic technology: **A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO_2 films** by Brian O'Regan & Michael Grätzel.

Self-assembling photovoltaic technology that repairs itself

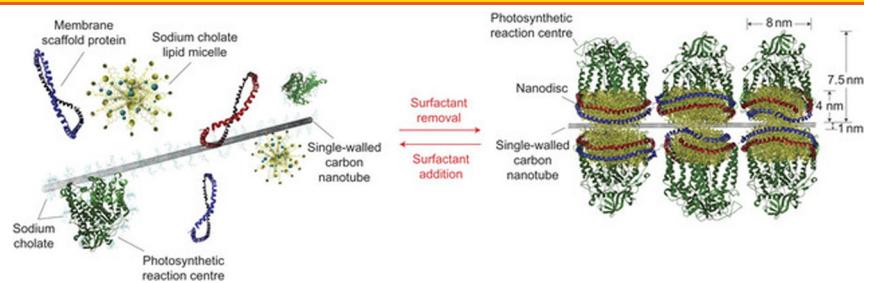
Josep Saldaña, September 6, 2010
tags: photosynthesis + energy + self-assembly + nanophotonics

Plants are good at doing what scientists and engineers have been struggling to do for decades: converting sunlight into stored energy, and doing so reliably day after day, year after year. Now some MIT scientists have succeeded in mimicking a key aspect of that process. One of the problems with harvesting sunlight is that the sun's rays can be highly destructive to many materials. Sunlight leads to a gradual degradation of many systems developed to harness it. But plants have adopted an interesting strategy to address this issue: They constantly break down their light-capturing molecules and reassemble them from scratch, so the basic structures that capture the sun's energy are, in effect, always brand new.

That process has now been imitated by Michael Strano and his team of graduate students and researchers.

They have created a novel set of self-assembling molecules that can turn sunlight into electricity; the molecules can be repeatedly broken down and then reassembled quickly, just by adding or removing an additional solution. Strano says the idea first occurred to him when he was reading about plant biology. "I was really impressed by how plant cells have this extremely efficient repair mechanism," he says. In full summer sunlight, "a leaf on a tree is recycling its proteins about every 45 minutes, even though you might think of it as a static photocell."

One of Strano's long-term research goals has been to find ways to imitate principles found in nature using nanocomponents. To imitate photosynthesis, Strano and his team produced synthetic molecules called phospholipids that form discs; these discs provide structural support for other molecules that actually respond to light, in structures called reaction centers, which release electrons when struck by particles of light. The discs, carrying the reaction centers,



Schematic of self-assembled photoelectrochemical complexes.

are in a solution where they attach themselves spontaneously to carbon nanotubes. The nanotubes hold the phospholipid discs in a uniform alignment so that the reaction centers can all be exposed to sunlight at once, and they also act as wires to collect and channel the flow of electrons knocked loose by the reactive molecules.

The system Strano's team produced is made up of seven different compounds, including the carbon nanotubes, the phospholipids, and the proteins that make up the reaction centers, which under the right conditions spontaneously assemble themselves into a light-harvesting structure that produces an electric current. Strano says **he believes this sets a record for the complexity of a self-assembling system**. When a surfactant is added to the mix, the seven components all come apart and form a soupy solution. Then, when the researchers removed the surfactant by pushing the solution through a membrane, the compounds spontaneously assembled once again into a perfectly formed, rejuvenated photocell.

"We're basically imitating tricks that nature has discovered over millions of years" — in particular, "reversibility, the ability to break apart and reassemble," Strano says. The team came up with the system based on a theoretical analysis, but then decided to build a prototype cell to test it out. They ran the cell through repeated cycles of assembly and disassembly over a 14-hour period, with no loss of efficiency.

Strano says that in devising novel

systems for generating electricity from light, researchers don't often study how the systems change over time. For conventional silicon-based photovoltaic cells, there is little degradation, but with many new systems being developed — either for lower cost, higher efficiency, flexibility or other improved characteristics — the degradation can be very significant. "Often people see, over 60 hours, the efficiency falling to 10 percent of what you initially saw," he says.

The individual reactions of these new molecular structures in converting sunlight are about 40 percent efficient, or about double the efficiency of today's best commercial solar cells.

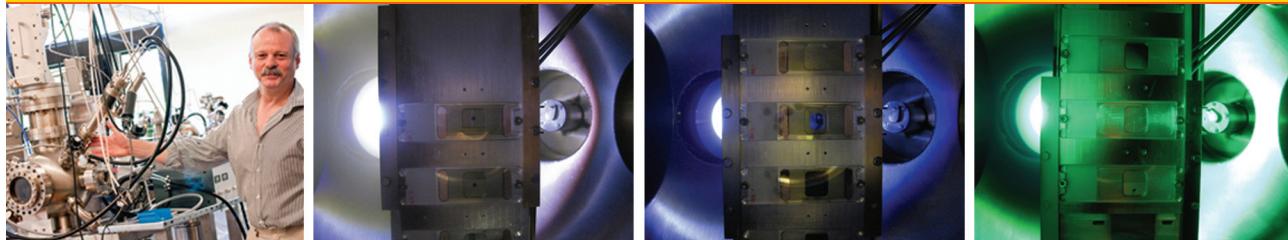
Theoretically, the efficiency of the structures could be close to 100 percent, he says. But in the initial work, the concentration of the structures in the solution was low, so the overall efficiency of the device was very low. They are working now to find ways to greatly increase the concentration.

Source: New self-assembling photovoltaic technology that repairs itself by David L. Chandler. This work is detailed in the paper **Photoelectrochemical complexes for solar energy conversion that chemically and autonomously regenerate**

by Moon-Ho Ham, Jong Hyun Choi, Ardemis A. Boghossian, Esther S. Jeng, Rachel A. Graff, Daniel A. Heller, Alice C. Chang, Aidas Mattis, Timothy H. Bayburt, Yelena V. Grinkova, Adam S. Zeiger, Krystyn J. Van Vliet, Erik K. Hobbie, Stephen G. Sligar, Colin A. Wright & Michael S. Strano

Turn windows into power generators

josep saldaña, August 23, 2010
tags: energy + nanoparticles + architecture + video



Images depicting the inside of the deposition chamber taken when scientists are depositing the insulating film. The different colours are due to the different gases being used.
Credit: Prof. Chris Binns, University of Leicester.

An international team of scientists and industrialists is to meet at the University of Leicester to develop a revolutionary new technique for harnessing green energy. Norwegian company EnSol AS has patented **a ground breaking, novel thin film solar cell technology** which they seek to develop commercially by 2016. The company is now working with experts in the University of Leicester Department of Physics and Astronomy to develop the revolutionary new type of solar cell material that could be coated as a thin film on, for example, windows in buildings to produce power on a large scale.

Professor of Nanotechnology at the University of Leicester, Professor Chris Binns, said the collaboration offered a tremendous opportunity to develop a new method for harnessing solar energy: "The material has been designed by EnSol AS and is based on nanoparticles that can be synthesised in Leicester. In fact, following some initial investment by the company, the equipment we have here at the University of Leicester is uniquely suited in the world to produce small amounts of the material for prototypes. The work is important since the solar cells are based on a new operating principle and different to Si solar cells. One of the key advantages is that it is a transparent thin film that

can be coated onto window glass so that windows in buildings can also become power generators. Obviously some light has to be absorbed in order to generate power but the windows would just have a slight tinting (though a transmission of only 8-10% is common place for windows in the "sun belt" areas of the world). Conversely the structural material of the building can also be coated with a higher degree of absorption. This could be side panels of the building itself, or even in the form of "clip-together" solar roof tiles. Also since it is a thin film that can be coated onto large areas it could become very much cheaper than conventional devices. **Photovoltaics are destined to form a key power generating method as part of a low carbon economy and the new technology will bring that a stage closer.**"

The material is composed of metal nanoparticles (diameters ~ 10 nm) embedded in a transparent composite matrix.

A spokesperson for EnSol AS said: "The basic cell concept has been demonstrated, and it will be the objective of this research and development project to systematically refine this PV cell technology to achieve a cell efficiency of 20% or greater. A thin film deposition system with nano-

particle source, will be designed and constructed in collaboration with the University of Leicester for the fabrication of prototype cells based on this design. This experimental facility will be designed to produce PV cells with an active area in excess of 16 cm² (40 mm x 40 mm) deposited onto standard glass substrates. These prototype cells will subsequently be characterised and tested in collaboration with our academic partners. EnSol's **next generation PV cell technology has tremendous potential for industrial scale, low environmental impact, cost effective production via standard "spray on" techniques.**"

Source: New technique announced to turn windows into power generators. Norwegian company EnSol AS to develop unique patented technology in collaboration with University of Leicester

Car of the future powered by their bodywork

josép saldaña, October 1, 2010
tags: carbon nanotubes + energy

Imperial College London



→ Demonstration of new type of battery technology

Imagine a car which body also serves as a rechargeable battery. A battery that stores braking energy while you drive and that also stores energy when you plug in the car overnight to recharge. At the moment this is just a fascinating idea, but tests are currently under way to see if the vision can be transformed into reality. Volvo Cars is one out of nine participants in an international materials development project.

Among the foremost challenges in the development of hybrids and electric cars are the size, weight and cost of the current generation of batteries. In order to deliver sufficient capacity using today's technology, it is necessary to fit large batteries, which in turn increases the car's weight.

Earlier this year, a materials development project was launched by Imperial College in London that brings together nine European companies and institutes. Volvo Cars is the only car manufacturer participating in the project. With the help of 35 million SEK (approx. 3.5 million EURO) in financial support from the European Union (EU), a composite blend of carbon fibres and polymer resin is being developed that can store and charge more energy faster than conventional batteries can. At the same time, the material

is extremely strong and pliant, which means it can be shaped for use in building the car's body panels. According to calculations, the car's weight could be cut by as much as 15 percent if steel body panels were replaced with the new material.

The project will continue for three years. In the first stage, work focuses both on developing the composite material so it can store more energy and on studying ways of producing the material on an industrial scale. Only in the final stage will the battery be fitted to a car.

"Our role is to contribute expertise on how this technology can be integrated in the future and to input ideas about the advantages and disadvantages in terms of cost and user-friendliness," says Per-Ivar Sellergren, development engineer at the Volvo Cars Materials Centre.

Initially, the car's spare wheel recess will be converted into a composite battery. "This is a relatively large structure that is easy to replace. Not sufficiently large to power the entire car, but enough to switch the engine off and on when the car is at a standstill, for instance at traffic lights," says Per-Ivar Sellergren.

If the project is successful, there are many possible application areas. For

instance, mobile phones will be able to be as slim as credit cards and laptops will manage longer without needing to be recharged.

Source: From Tomorrow's Volvo car: body panels serve as the car battery

The researchers say that the composite material that they are developing, which is made of carbon fibres and a polymer resin, will store and discharge large amounts of energy much more quickly than conventional batteries.

In addition, **the material does not use chemical processes, making it quicker to recharge than conventional batteries. Furthermore, this recharging process causes little degradation in the composite material, because it does not involve a chemical reaction, whereas conventional batteries degrade over time.**

For the first stage of the project, the scientists are planning to further develop their composite material so that it can store more energy. The team will improve the material's mechanical properties by growing carbon nanotubes on the surface of the carbon fibres, which should also increase the surface area of the material, which would improve its capacity to store more energy.

Source: From Cars of the future could be powered by their bodywork thanks to new battery technology

Next Solar Impulse aircraft and nanotechnology

josep saldaña, August 13, 2010
tags: nanomaterial + carbon nanotubes + energy + video



Illustration of the Solar Impulse prototype. Credit: Solar Impulse/EPFL Claudio Leonardi.

The Solar Impulse aircraft, which is powered only by solar energy, has triumphantly completed its first night flight. The ultralight aircraft was airborne for a total of 26 hours – from 7 am on July 7 until 9 am the following day (Central European Time) – before finally landing as planned at Payerne airbase in Switzerland. It is now officially **the first manned aircraft capable of flying day and night without fuel, powered entirely by solar energy.**

"We extend our sincere congratulations to Bertrand Piccard and André Borschberg of Solar Impulse, and are delighted to be part of this terrific achievement," says Patrick Thomas, CEO of Bayer MaterialScience. "This is a further milestone on the way to the first solar-powered circumnavigation of the globe. We are proud to be an official partner of the Solar Impulse project and to make a further positive contribution to climate-friendly mobility with our innovative materials."

In 2013 a second prototype is scheduled to fly right round the world in five

stages, each lasting five days, traveling at an average speed of 70 km/h. **Source:** BAYNEWS - The Bayer Press Server - Solar Impulse aircraft successfully completes its first night flight. Bayer MaterialScience contributes innovative materials to long-range solar-powered aircraft

Bayer MaterialScience has become an official partner of the Solar Impulse project. Its founders Bertrand Piccard and André Borschberg are developing the first manned aircraft aiming to fly around the world day and night without fuel, propelled by solar energy only. The latest cutting-edge technology is incorporated into the prototype airplane, which has the wingspan of a large airliner (63.40 meters) and the weight of a midsize car (1.600 kilograms). Some 12,000 solar cells cover its surface to run 4 electrical engines and store the solar energy for the night in 400 kilograms of lithium batteries.

Bayer MaterialScience will support the Swiss-based Solar Impulse initiative with technical expertise, high-tech polymer materials and energy-saving

lightweight products. **Baytubes® carbon nanotubes from Bayer MaterialScience, for example, could increase battery performance and improve the strength of structural components while keeping their weight to a minimum.** Other potential applications include innovative adhesives, polyurethane rigid foams for paneling in the cockpit and engine, and extremely thin yet break-resistant polycarbonate films and sheet for the cockpit glazing.

Bertrand Piccard, Initiator of Solar Impulse, says support from Bayer MaterialScience is a significant boost for the project. "**I've always been fascinated by nanotechnology.** Now, with Bayer MaterialScience as an official partner, we will be able to make our airplane even lighter and more efficient. We look forward with great enthusiasm to being able to tap into the company's renowned expertise and innovative materials."

Source: Bayer MaterialScience becomes official partner for Solar Impulse.

Nanowires battery can hold 10 times the charge of existing Li-ion battery

josép saldaña, December 14, 2010
tags: energy

Researchers have **found a way to use silicon nanowires to reinvent the rechargeable lithium-ion batteries** that power laptops, iPods, video cameras, cell phones, and countless other devices.

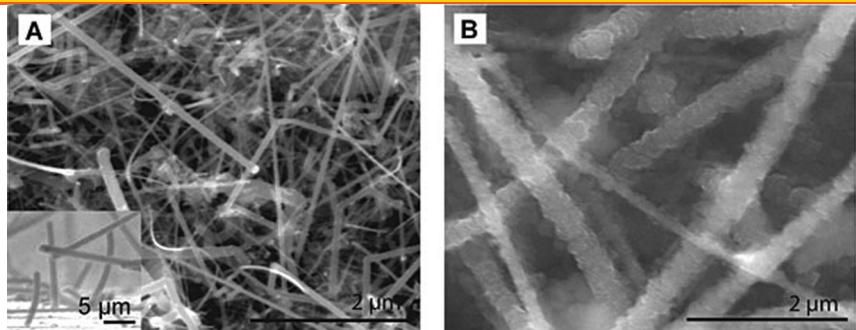
The new technology, developed through research led by Yi Cui, assistant professor of materials science and engineering at Stanford, produces 10 times the amount of electricity of existing lithium-ion, known as Li-ion, batteries. **A laptop that now runs on battery for two hours could operate for 20 hours**, a boon to ocean-hopping business travelers. "It's not a small improvement," Cui said. "It's a revolutionary development."

The greatly expanded storage capacity could make Li-ion batteries attractive to electric car manufacturers. Cui suggested that **they could also be used in homes or offices to store electricity generated by rooftop solar panels.**

"Given the mature infrastructure behind silicon, this new technology can be pushed to real life quickly," Cui said.

The electrical storage capacity of a Li-ion battery is limited by how much lithium can be held in the battery's anode, which is typically made of carbon. Silicon has a much higher capacity than carbon, but also has a drawback.

Silicon placed in a battery swells as it absorbs positively charged lithium atoms during charging, then shrinks during use (i.e., when playing your iPod) as the lithium is drawn out of the silicon. This expand/shrink cycle typically causes the silicon (often in the form of particles or a thin film) to pulverize, degrading the performance of the battery.



Photos taken by a scanning electron microscope of silicon nanowires before (left) and after (right) absorbing lithium. Both photos were taken at the same magnification.
Courtesy Nature Nanotechnology.

Cui's battery gets around this problem with nanotechnology. The lithium is stored in a forest of tiny silicon nanowires, each with a diameter one-thousandth the thickness of a sheet of paper. The nanowires inflate four times their normal size as they soak up lithium. But, unlike other silicon shapes, they do not fracture.

Research on silicon in batteries began three decades ago. Chan explained: "The people kind of gave up on it because the capacity wasn't high enough and the cycle life wasn't good enough. And it was just because of the shape they were using. It was just too big, and they couldn't undergo the volume changes." Then, along came silicon nanowires. "We just kind of put them together," Chan said.

Cui said that a patent application has been filed. He is considering formation of a company or an agreement with a battery manufacturer. Manufacturing the nanowire batteries would require "one or two different steps, but the process can certainly be scaled up," he added. "It's a well understood process."

Source: From Nanowire battery can hold 10 times the charge of existing lithium-ion battery By Dan Stober. This work is detailed in the paper "High-performance lithium battery anodes using silicon nanowires" by Candace K. Chan, Hailin Peng, Gao Liu, Kevin McIlwrath, Xiao Feng Zhang, Robert A. Huggins & Yi Cui .

Abstract

There is great interest in developing rechargeable lithium batteries with higher energy capacity and longer cycle life for applications in portable electronic devices, electric vehicles and implantable medical devices. Silicon is an attractive anode material for lithium batteries because it has a low discharge potential and the highest known theoretical charge capacity (4,200 mAh g⁻¹). Although this is more than ten times higher than existing graphite anodes and much larger than various nitride and oxide materials, silicon anodes have limited applications because silicon's volume changes by 400% upon insertion and extraction of lithium which results in pulverization and capacity fading. Here, we show that silicon nanowire battery electrodes circumvent these issues as they can accommodate large strain without pulverization, provide good electronic contact and conduction, and display short lithium insertion distances. We achieved the theoretical charge capacity for silicon anodes and maintained a discharge capacity close to 75% of this maximum, with little fading during cycling.

Scanning probe microscopy reveal battery behavior at the nanoscale

josep saldaña, October 4, 2010
tags: microscope + energy

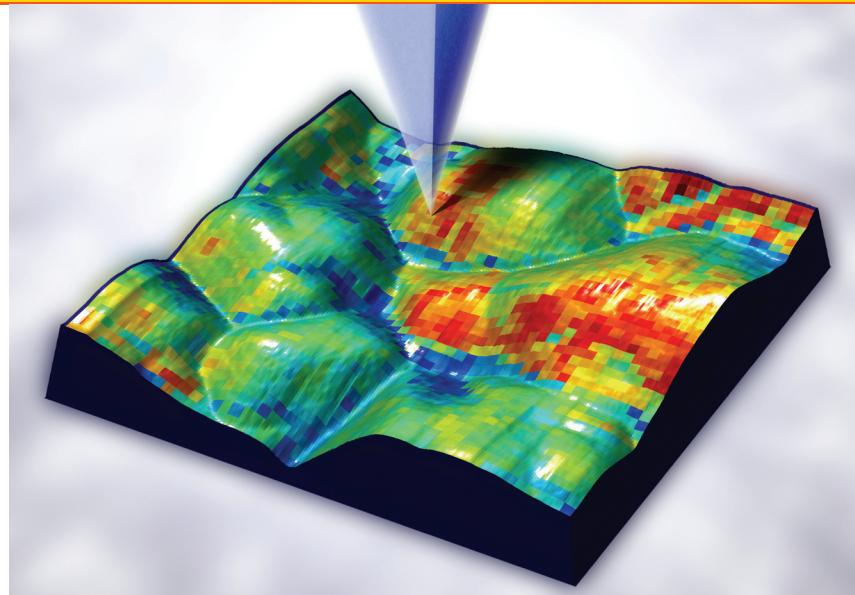
As industries and consumers increasingly seek improved battery power sources, **cutting-edge microscopy performed at the Department of Energy's Oak Ridge National Laboratory is providing an unprecedented perspective on how lithium-ion batteries function.**

A research team led by ORNL's Nina Balke, Stephen Jesse and Sergei Kalinin has developed a new type of scanning probe microscopy called electrochemical strain microscopy (ESM) to examine the movement of lithium ions through a battery's cathode material. Balke, Jesse and Kalinin are research scientists at ORNL's Center for Nanophase Materials Science.

"We can provide a detailed picture of ionic motion in nanometer volumes, which exceeds state-of-the-art electrochemical techniques by six to seven orders of magnitude," Kalinin said. Researchers achieved the results by applying voltage with an ESM probe to the surface of the battery's layered cathode. By measuring the corresponding electrochemical strain, or volume change, the team was able to visualize how lithium ions flowed through the material. Conventional electrochemical techniques, which analyze electric current instead of strain, do not work on a nanoscale level because the electrochemical currents are too small to measure, Kalinin explained. "These are the first measurements, to our knowledge, of lithium ion flow at this spatial resolution," Kalinin said.

Lithium-ion batteries, which power electronic devices from cell phones to electric cars, are valued for their low weight, high energy density and recharging ability. Researchers hope to extend the batteries' performance by lending engineers a finely tuned knowledge of battery components and dynamics.

"We want to understand - from a



A new electrochemical strain microscopy (ESM) technique developed at Oak Ridge National Laboratory can map lithium ion flow through a battery's cathode material. This 1 micron x 1 micron composite image demonstrates how regions on a cathode surface display varying electrochemical behaviors when probed with ESM.

nanoscale perspective - what makes one battery work and one battery fail. This can be done by examining its functionality at the level of a single grain or an extended defect," Balke said. "Very small changes at the nanometer level could have a huge impact at the device level," Balke said. "Understanding the batteries at this length scale could help make suggestions for materials engineering."

Although the research focused on lithium-ion batteries, the team expects that its technique could be used to measure other electrochemical solid-state systems, including other battery types, fuel cells and similar electronic devices that use nanoscale ionic motion for information storage.

"We see this method as an example of the kinds of higher dimensional scanning probe techniques that we are developing at CNMS that enable us to see the inner workings of complex materials at the nanoscale," Jesse said. "Such capabilities are particularly relevant to the increasingly important area of energy research."

Source: ORNL scientists reveal battery behavior at the nanoscale. This work is detailed in the paper *Nanoscale mapping of ion diffusion in a lithium-ion battery cathode* by N. Balke, S. Jesse, A. N. Morozovska, E. Eliseev, D. W. Chung, Y. Kim, L. Adamczyk, R. E. García, N. Dudney & S. V. Kalinin.

Abstract

The movement of lithium ions into and out of electrodes is central to the operation of lithium-ion batteries. Although this process has been extensively studied at the device level, it remains insufficiently characterized at the nanoscale level of grain clusters, single grains and defects. Here, we probe the spatial variation of lithium-ion diffusion times in the battery-cathode material LiCoO₂ at a resolution of ~100 nm by using an atomic force microscope to both redistribute lithium ions and measure the resulting cathode deformation. The relationship between diffusion and single grains and grain boundaries is observed, revealing that the diffusion coefficient increases for certain grain orientations and single-grain boundaries. This knowledge provides feedback to improve understanding of the nanoscale mechanisms underpinning lithium-ion battery operation.

World's smallest battery offers “a view never before seen” to improve batteries

josép saldaña, December 12, 2010
tags: energy + microscope



SnO₂ nanowire before charging
SnO₂ nanowire after charging, elongation 90%, diameter expansion 35%, volume expansion 250%

The Medusa twist: formerly unobserved increase in length and twist of the anode in a nanobattery. (Courtesy DOE Center for Integrated Nanotechnologies)

A benchtop version of the world's smallest battery — its anode a single nanowire one seven-thousandth the thickness of a human hair — has been created by a team led by Sandia National Laboratories researcher Jianyu Huang. To better study the anode's characteristics, the tiny rechargeable, lithium-based battery was formed inside a transmission electron microscope (TEM) at the Center for Integrated Nanotechnologies (CINT), a Department of Energy research facility jointly operated by Sandia and Los Alamos national laboratories.

Says Huang, “**This experiment enables us to study the charging and discharging of a battery in real time and at atomic scale resolution, thus enlarging our understanding of the fundamental mechanisms by which batteries work.**” Because nanowire-based materials in lithium ion batteries offer the potential for significant improvements in power and energy density over bulk electrodes, more stringent investigations of their operating properties should improve new generations of plug-in hybrid electric vehicles, laptops and cell phones.

The tiny battery created by Huang and co-workers consists of a single tin oxide nanowire anode 100 nanometers in diameter and 10 micrometers long, a bulk lithium cobalt oxide cathode three millimeters long, and an ionic liquid electrolyte. The device offers the ability to directly observe change in atomic structure during charging and discharging.

An unexpected find of the researchers was that the tin oxide nanowire rod nearly doubles in length during charging — far more than its diameter increases — a fact that could help avoid short circuits that may shorten battery life. “Manufacturers should take account of this elongation in their battery design,” Huang said. (The common belief of workers in the field has been that batteries swell across their diameter, not longitudinally.) Huang’s group found this flaw by following the progression of the lithium ions as they travel along the nanowire and create what researchers christened the “Medusa front” — an area where high density of mobile dislocations cause the nanowire to bend and wiggle as the front progresses. The web of dislocations is caused by lithium penetration of the crystalline lattice. “These observations prove that nanowires can sustain large stress (>10 GPa) induced by lithiation without breaking, indicating that nanowires are very good candidates for battery electrodes,” said Huang. “Our observations — which initially surprised us — tell battery researchers how these dislocations are generated, how they evolve during charging, and offer guidance in how to mitigate them,” Huang said. “This is the closest view to what’s happening during charging of a battery that researcher have achieved so far.”

“The methodology that we developed should stimulate extensive real-time studies of the microscopic processes in batteries and lead to a more complete understanding of the mechanisms governing battery performance and reliability,” he said. “Our experi-

ments also lay a foundation for in-situ studies of electrochemical reactions, and will have broad impact in energy storage, corrosion, electrodeposition and general chemical synthesis research field.”

Source: From World's smallest battery created at CINT nanotechnology center. This work is detailed in the paper *In Situ Observation of the Electrochemical Lithiation of a Single SnO₂ Nanowire Electrode* by Jian Yu Huang, Li Zhong, Chong Min Wang, John P. Sullivan, Wu Xu, Li Qiang Zhang, Scott X. Mao, Nicholas S. Hudak, Xiao Hua Liu, Arunkumar Subramanian, Hongyou Fan, Liang Qi, Akihiro Kushima and Ju Li.

Abstract

We report the creation of a nanoscale electrochemical device inside a transmission electron microscope—consisting of a single tin dioxide (SnO₂) nanowire anode, an ionic liquid electrolyte, and a bulk lithium cobalt dioxide (LiCoO₂) cathode—and the *in situ* observation of the lithiation of the SnO₂ nanowire during electrochemical charging. Upon charging, a reaction front propagated progressively along the nanowire, causing the nanowire to swell, elongate, and spiral. The reaction front is a “Medusa zone” containing a high density of mobile dislocations, which are continuously nucleated and absorbed at the moving front. This dislocation cloud indicates large in-plane misfit stresses and is a structural precursor to electrochemically driven solid-state amorphization. Because lithiation-induced volume expansion, plasticity, and pulverization of electrode materials are the major mechanical effects that plague the performance and lifetime of high-capacity anodes in lithium-ion batteries, our observations provide important mechanistic insight for the design of advanced batteries.

Could 135,000 Laptops Help Solve the Energy Challenge?

josep saldaña, December 8, 2010
tags: energy + climate + video



x 135,000 ?

U.S Energy Secretary Steven Chu announced the largest ever awards of the Department's supercomputing time to 57 innovative research projects - **using computer simulations to perform virtual experiments that in most cases would be impossible or impractical in the natural world.** Utilizing two world-leading supercomputers with a computational capacity roughly equal to 135,000 quad-core laptops, the research could, for example, help speed the development of more efficient solar cells, improvements in biofuel production, or more effective medications to help slow the progression of Parkinson's disease. Specifically, the Department is awarding time on two of the world's fastest and most powerful supercomputers — the Cray XT5 ("Jaguar") at Oak Ridge National Laboratory and the IBM Blue Gene/P ("Intrepid") at Argonne National Laboratory. Jaguar's computational capacity is roughly equivalent to 109,000 laptops all working together to solve the same problem. Intrepid is roughly equivalent to 26,000 laptops. Awarded under the Department's Innovative and Novel

Computational Impact on Theory and Experiment (INCITE) program, many of the new and continuing INCITE projects **aim to further renewable energy solutions and understand of the environmental impacts of energy use.**

One award for improving battery technology is profiled below in brief summary.

Understanding the Ultimate Battery Chemistry: Rechargeable Lithium/Air

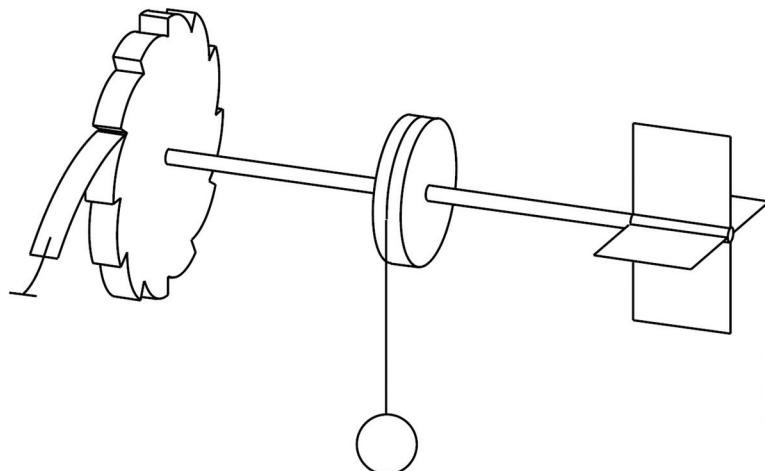
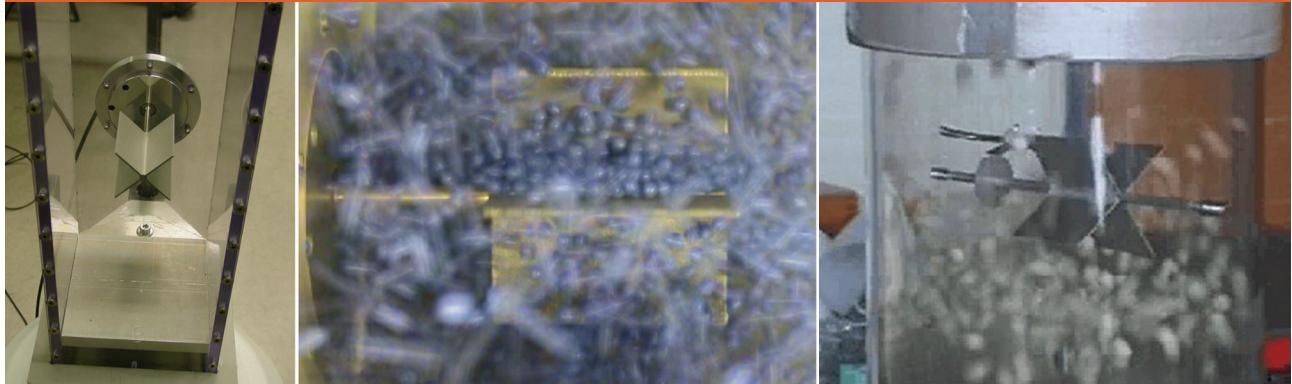
Principal Investigator: Jack Wells, Oak Ridge National Laboratory
Utilizing both the Jaguar and Intrepid supercomputers, the research consortium will study and demonstrate a working prototype of a rechargeable Lithium/Air battery. The Lithium/Air battery can potentially store ten times the energy of a Lithium/Ion battery of the same weight. Realizing this enormous potential is a very challenging scientific problem. If successful, this will enable rechargeable batteries that compete directly with gasoline, making fully electric vehicles practical and widespread.

Read the full listing of awards, with detailed technical descriptions [among others: Petascale Modeling of Nano-electronic Devices, Probing the Non-Scalable Nano Regime in Catalytic Nanoparticles with Electronic Structure Calculations, Electronic Structure Calculations for Nanostructures].

Source: Could 135,000 Laptops Help Solve the Energy Challenge?. Department of Energy Supercomputers to Pursue Breakthroughs in Biofuels, Nuclear Power, Medicine, Climate Change and Fundamental Research

Converting brownian motion into work

josep saldaña, June 22, 2010
tags: nanodevice + nanomachinery + energy



Researchers from the Foundation for Fundamental Research on Matter and University of Twente in the Netherlands, and the University of Patras in Greece have for the first time experimentally realised, almost a century later, an idea dating from 1912. In that year the physicist Smoluchowski devised a prototype for an engine at the molecular scale in which he thought he could ingeniously convert Brownian motion into work. The team of scientists have now successfully constructed this device at the much larger scale of a granular gas. Moreover, they have shown that an intriguing exchange takes place between the vanes of the engine and the granular gas: once the vanes have started rotating, they in turn induce a rotating motion in the gas, a so-called convection roll. This reinforces the movement

of the device and allows for a virtually continuous rotation. Molecular motors, such as those responsible for tensing and relaxing your muscles, move in a strange manner: they propel themselves forwards despite - or thanks to - a continuous bombardment of the randomly moving molecules in their surroundings. **This random movement is called Brownian motion and a well-constructed motor at the nanoscale actually makes use of this to generate a directed movement (and therefore work). The device introduced by the physicist Marian Smoluchowski in 1912, as a thought experiment, is a classical example of such a motor.**

Source: From Classical thought experiment brought to life in granular gas. This work is detailed in the paper Ex-

(top) The thought experiment is brought to life in a granular gas: the experimental setup (left) and the device in operation (center and right).

(left) Smoluchowski's thought experiment with the vanes on the right, the cog on the left and in the middle a pulley with a weight.

perimental Realization of a Rotational Ratchet in a Granular Gas by Peter Eshuis, Ko van der Weele, Detlef Lohse, and Devaraj van der Meer. "We construct a ratchet of the Smoluchowski-Feynman type, consisting of four vanes that are allowed to rotate freely in a vibrofluidized granular gas. The necessary out-of-equilibrium environment is provided by the inelastically colliding grains, and the equally crucial symmetry breaking by applying a soft coating to one side of each vane. The onset of the ratchet effect occurs at a critical shaking strength via a smooth, continuous phase transition. For very strong shaking the vanes interact actively with the gas and a convection roll develops, sustaining the rotation of the vanes."

See **movies of the experiment**.

Self-Powered Nanosensors

josep saldaña, April 12, 2010
tags: energy + detection

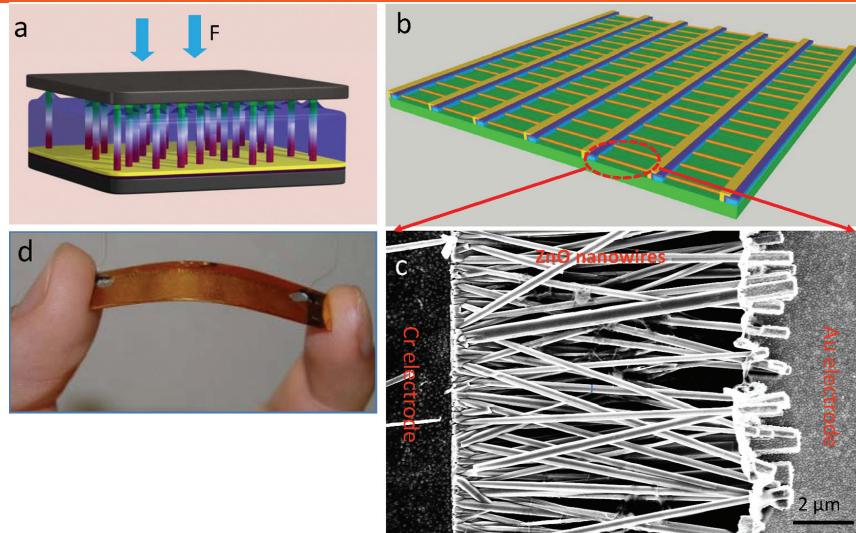


Figure shows (a) Fabrication of a vertical-nanowire integrated nanogenerator (VING), (b) Design of a lateral-nanowire integrated nanogenerator (LING) array, (c) Scanning electron microscope image of a row of laterally-grown zinc oxide nanowire arrays, and (d) Image of the LING structure. Credit: Zhong Lin Wang.

By combining a new generation of piezoelectric nanogenerators with two types of nanowire sensors, researchers have created what are believed to be **the first self-powered nanometer-scale sensing devices that draw power from the conversion of mechanical energy**. The new devices can measure the pH of liquids or detect the presence of ultraviolet light using electrical current produced from mechanical energy in the environment.

Based on arrays containing as many as 20,000 zinc oxide nanowires in each nanogenerator, the devices can produce up to 1.2 volts of output voltage, and are fabricated with a chemical process designed to facilitate low-cost manufacture on flexible substrates. Tests done with nearly one thousand nanogenerators – which have no mechanical moving parts – showed that they can be operated over time without loss of generating capacity.

"We have demonstrated a robust way to harvest energy and use it for power-

ing nanometer-scale sensors," said Zhong Lin Wang, a Regents professor in the School of Materials Science and Engineering at the Georgia Institute of Technology. "We now have a technology roadmap for scaling these nanogenerators up to make truly practical applications."

For the past five years, Wang's research team has been developing nanoscale generators that use the piezoelectric effect – which produces electrical charges when wires made from zinc oxide are subjected to strain. The strain can be produced by simply flexing the wires, and current from many wires can be constructively combined to power small devices. The research effort has recently focused on increasing the amount of current and voltage generated and on making the devices more robust.

The new generator and nano-scale sensors open new possibilities for very small sensing devices that can operate without batteries, powered by mechani-

cal energy harvested from the environment. Energy sources could include the motion of tides, sonic waves, mechanical vibration, the flapping of a flag in the wind, pressure from shoes of a hiker or the movement of clothing.

"Building devices that are small isn't sufficient," Wang noted. "We must also be able to power them in a sustainable way that allows them to be mobile. Using our new nanogenerator, we can put these devices into the environment where they can work independently and sustainably without requiring a battery."

Source: From Self-Powered Nanosensors: Researchers Use Improved Nanogenerators to Power Sensors Based on Zinc Oxide Nanowires by John Toon. This work is detailed in the paper Self-powered nanowire devices by Sheng Xu, Yong Qin, Chen Xu, Yaguang Wei, Rusen Yang & Zhong Lin Wang.

A Delicious New Solar Cell Technology

josép saldaña, May 8, 2010
tags: educational + energy

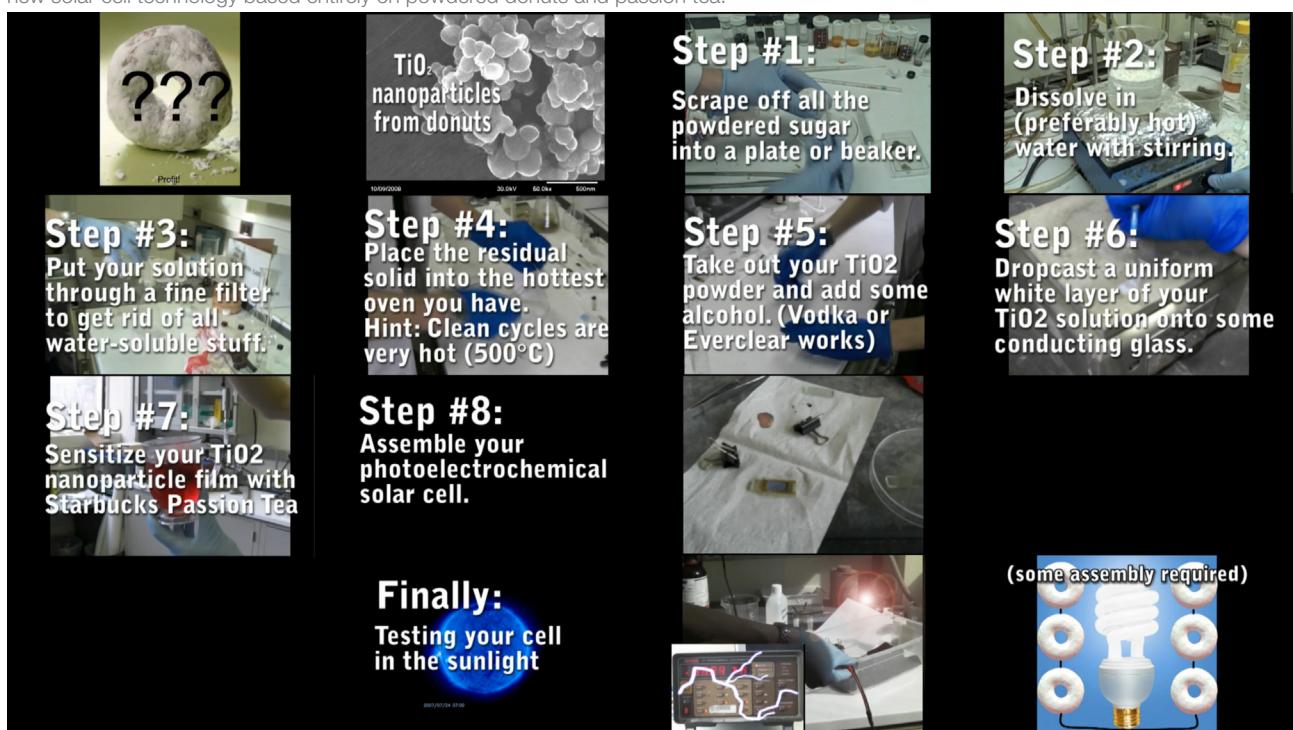


Researchers demonstrate a new solar cell technology: How To Make a Solar Cell with Donuts and Tea.

"It turns out these delicious little things contain everything we need to make a simple solar cell," said Blake Farrow, a Canadian scientist who filmed the video while visiting Prashant Kamat's lab at the University of Notre Dame.

Notre Dame's YouTube Channel

Frames from the video A Delicious New Solar Cell Technology, researchers demonstrate a new solar cell technology based entirely on powdered donuts and passion tea.



Nanotechnology, climate and energy: Over-heated promises and hot air?

josep saldaña, November 17, 2010
tags: public opinion + concerns + climate + energy

Friends of the Earth groups around the world released the report, Nanotechnology, climate and energy: Over-heated promises and hot air?, debunking the promises made by the nanotechnology industry about its ability to increase energy efficiency and alleviate climate change.

The report delves into the complex issues raised by nanotechnology and concludes that nanotechnology fails to exhibit much potential as a solution to global warming, resource depletion or pollution.

"Despite claims that nanotechnology can limit climate change and promote energy efficiency, we've found that the use of nanotechnology actually comes at a large environmental cost," said Ian Illuminato of Friends of the Earth U.S., a coauthor of the report. "Rather than substantively reducing our environmental footprint, it instead allows people to continue with 'business as usual' and avoid serious improvements in energy efficiency and behavioral changes."

"Worse, the report reveals that the world's biggest petrochemical companies have established a joint, U.S.-based, consortium to use nanotechnology to find and extract more oil and gas, which would have extremely adverse environmental impacts."

According to the report, nanotechnology has the potential to transform the way we harness, use and store energy. However, the manufacture of nanotechnology products requires large amounts of energy, and the products may not deliver promised energy. The report also highlights how the technology is primarily used in products that do not provide energy savings, such as clothing, cosmetics and sporting goods.

In response to the report, 350.org founder Bill McKibben said, "Very few people have looked beyond the shiny

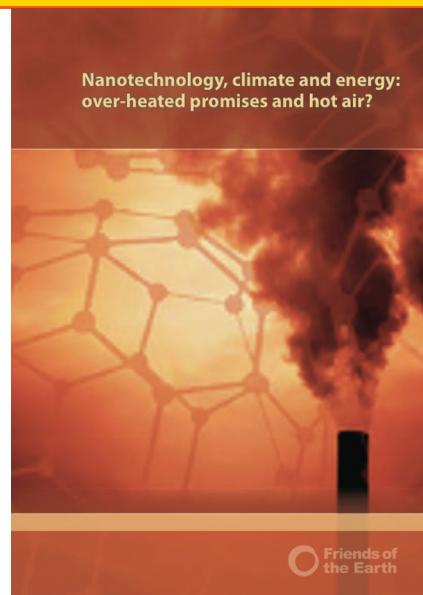
promise of nanotechnology to try and understand how this far-reaching new technique is actually developing. This report is an excellent glimpse inside, and it offers a judicious and balanced account of a subject we need very much to be thinking about."

"Nanotechnology has been the focus of considerable 'green-wash' and industry has promoted it as a solution to environmental concerns. It is important the public understands that many nanotechnology applications actually come at a high environmental cost. Worse, at a time when we need to reduce our reliance on fossil fuels, there is growing investment in nanotechnology to find and extract more oil and gas," said report coauthor Georgia Miller, of Friends of the Earth Australia.
Source: Nanotechnology's true climate and energy cost exposed. Report reveals large net energy cost and other environmental threats posed by nanotechnology by Friends of the Earth

Andrew Maynard over at his 2020 Science blog takes a first look at the report, which provides a cursory breakdown and appraisal of the report in order to assist readers in forming their own opinion on its importance and implications. "I've only had the chance to skim through the report so far, and so don't have detailed comments on it. But on my initial skim a number of things struck me:

- The report is written from a specific perspective that questions the validity of claims made of nanotechnology – especially that it will "deliver energy technologies that are efficient, inexpensive and environmentally sound"
- It is pretty comprehensive, covering nanotechnology and solar energy, wind energy, hydrogen energy,

Nanotechnology, climate and energy: over-heated promises and hot air?



Friends of the Earth new report cover

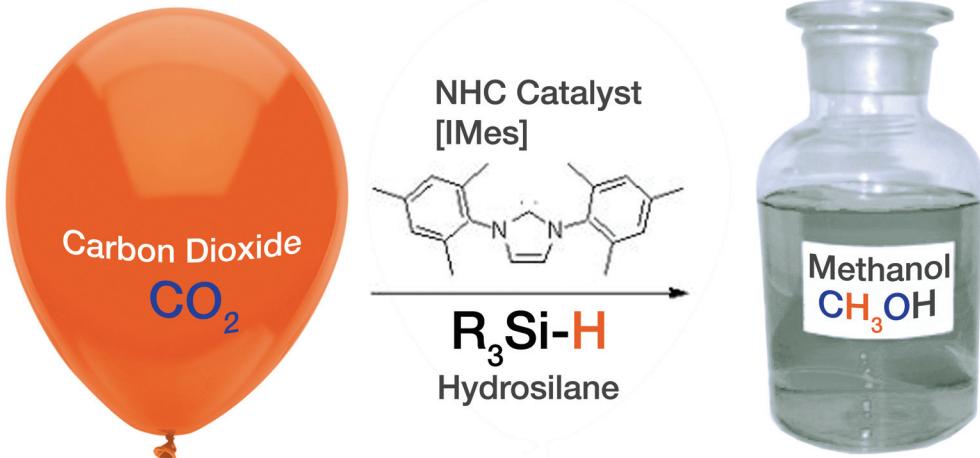
oil and gas extraction, batteries, supercapacitors, nanocoatings and insulators, catalysis and reinforced parts for airplanes and cars.

- However, it doesn't cover all nano-applications in the energy sector. Two examples are the use of heterogeneous catalysts in vehicle exhausts and to reduce the energy overheads of a multitude of processes, the use of nanomaterials to develop more efficient power lines.
- The report also tends to focus on areas where it is easier to construct position statements challenging statements on the positive use of nanomaterials.
- Nevertheless, **it appears to be a significant and well-written counterbalance to publications that promote the benefits of nanotechnology in the energy sector without deep and critical evaluation of the pros and cons of the technology.**

Are the issues raised valid and in need of further exploration? It's worth reading for yourself to decide."

Turn carbon dioxide into useful energy

josép saldaña, May 1, 2010
tags: climate + energy + green chemistry



Scientists have developed a **green catalytic cycle that could help solve some of the world's biggest challenges—global warming and renewable energy.**

Carbon dioxide (CO₂) is a major factor in global warming and the bête noir of climate change scientists. But if scientists at the A*STAR have any say in the matter, it could soon be turned into useful energy in a simple, inexpensive and eco-friendly way. A team at the Institute of Bioengineering and Nanotechnology (IBN) led by principal researcher Yugen Zhang has invented a method for converting CO₂ to into methanol (CH₃OH) using an organocatalyst system based on a class of compounds called N-heterocyclic carbenes (NHC). In recent years, demands for alternative energy sources to replace fossil fuels have been growing against the backdrop of rising concern about climate change, and methanol has great potential in the alternative energy arena as a biofuel. “CO₂ is a major greenhouse gas and a major cause for global warming. The energy crisis is also an urgent issue to tackle. If we can convert CO₂ to energy in a cost-effective manner, it would solve two problems in one shot. That is the motivation of our research,” says Zhang. Carbon dioxide is highly stable and difficult to break down,

and many researchers and companies have examined systems employing metal catalysts in combination with suitable reductants such as hydrogen gas (H₂) to convert it to other products. However, these efforts have been plagued with problems associated with the catalyst’s short usable life, its susceptibility to degradation by oxygen, and the huge amounts of energy required to reach the high temperatures and pressures needed for the reactions to proceed. On the other hand, most organocatalysts, as Zhang points out, are tolerant of oxygen and active at room temperature and moderate pressures. “Because we have selected the right catalyst and the right system, we can make the reaction happen under mild conditions,” he says. Despite the promising results so far, many obstacles still remain to be overcome before Zhang’s organocatalytic reaction can be applied industrially. According to the team leader, the most pressing challenge is not the scaling up of production or reducing the cost of the catalyst itself, but finding alternatives for the costly hydrosilane substrate. One candidate for this role is hydrogen gas, suggesting the tantalizing possibility of a tie up with other researchers working on splitting water into hydrogen and oxygen using light-activated catalysts. “If we can use the hydrogen to react with carbon

dioxide, the whole system would work nicely. That is what we are proposing,” says Zhang.

Source: Organocatalysts turn carbon dioxide into useful energy - A*STAR Research. This work is detailed in the paper Conversion of carbon dioxide to methanol with silanes over N-heterocyclic carbene catalysts by S. N. Riduan, Y. Zhang & J. Y. Ying.

Nanotechnologies for future mobile devices

josep saldaña, April 14, 2010
 tags: nanomaterial + nanoelectronics + detection + energy + video



Morph concept technologies. The Morph concept device is a bridge between highly advanced technologies and their potential benefits to end-users. This device concept showcases some revolutionary leaps being explored by Nokia Research Center (NRC) in collaboration with the Cambridge Nanoscience Centre (United Kingdom) – nanoscale technologies that will potentially create a world of radically different devices that open up an entirely new spectrum of possibilities.

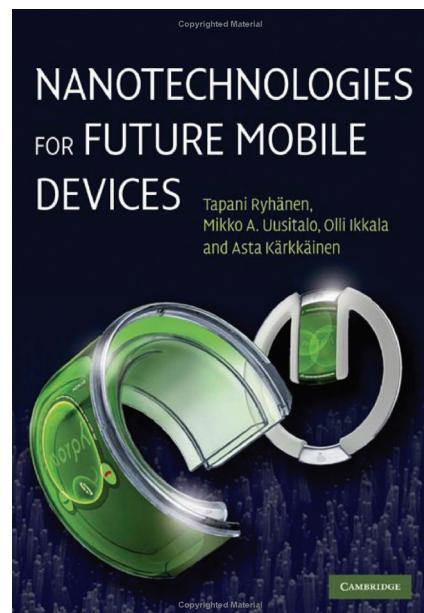
Since 2007 the Cambridge arm of the Nokia Research Center has been keenly hunched over the microscope, **exploring the possibilities of pioneering nanotechnology**.

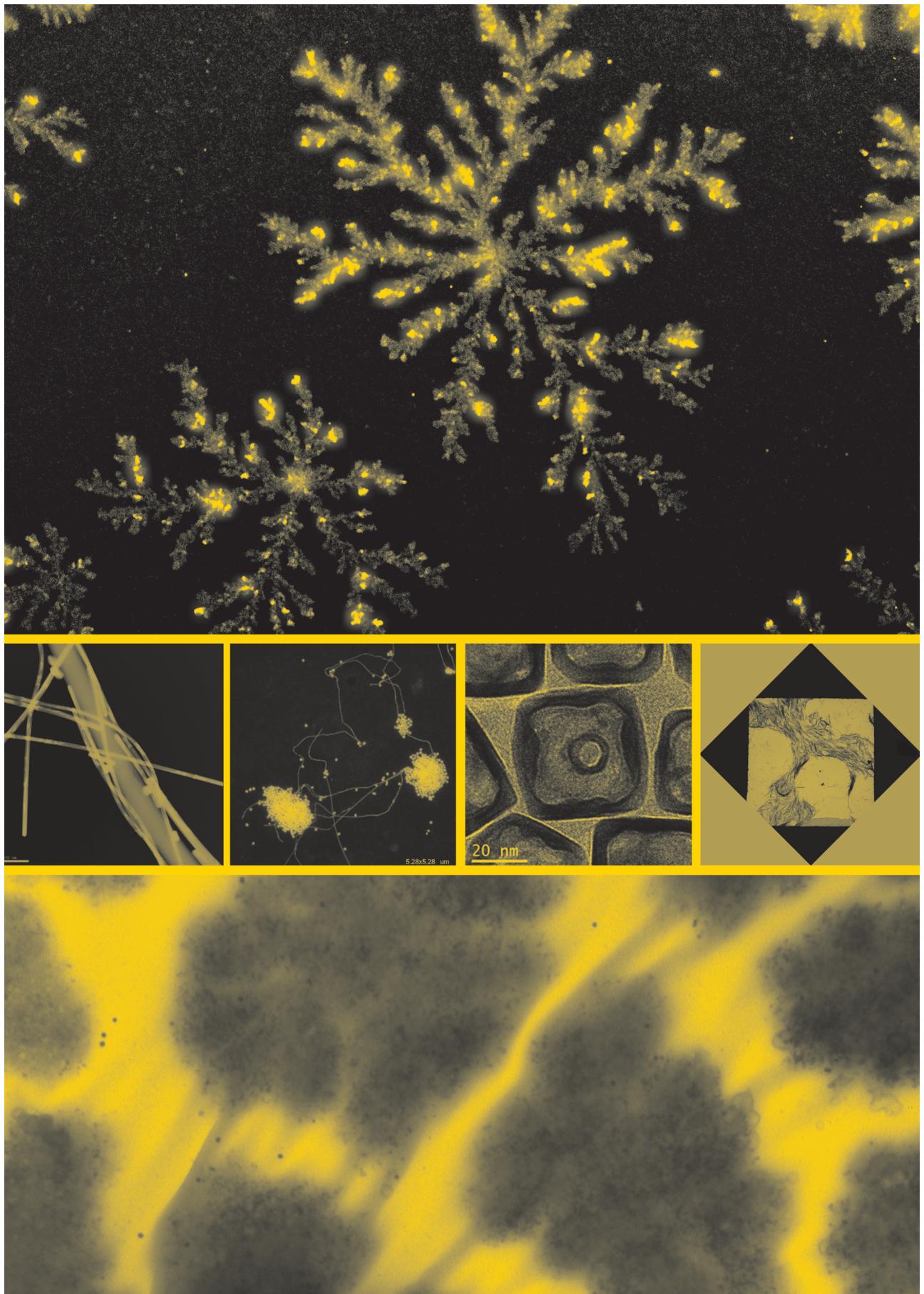
NRC's tight-knit collaboration with Cambridge University saw the Morph concept emerge from the laboratory, and now the teams are exploring the nanotechnology that could breathe life into this concept device of the future. However this fascinating research into nanotechnology isn't locked in an subterranean vault. In fact the research team are so keen to share their studies that its published a book called '**Nanotechnologies for Future Mobile Devices**'.

The book highlights much of the ongoing research that's being investigated within the NRC team in Cambridge, and details the exploration of some pretty exciting concepts, such as using nanoscale engineering techniques to alter the construction of new materials and the surfaces of devices in the future. Plus, it delves into the details on battery capabilities and using nanoelectronics in the creation of sensors and radios. And those are just a handful of examples from the mountain of information explored in '**Nanotechnologies for Future Mobile Devices**'.

Recently, the Nokia Research Center in Cambridge was awarded the UK Nordic Business award for Research and Development by UK Trade and Investment for its pioneering studies in the use of nanotechnologies in mobile devices.

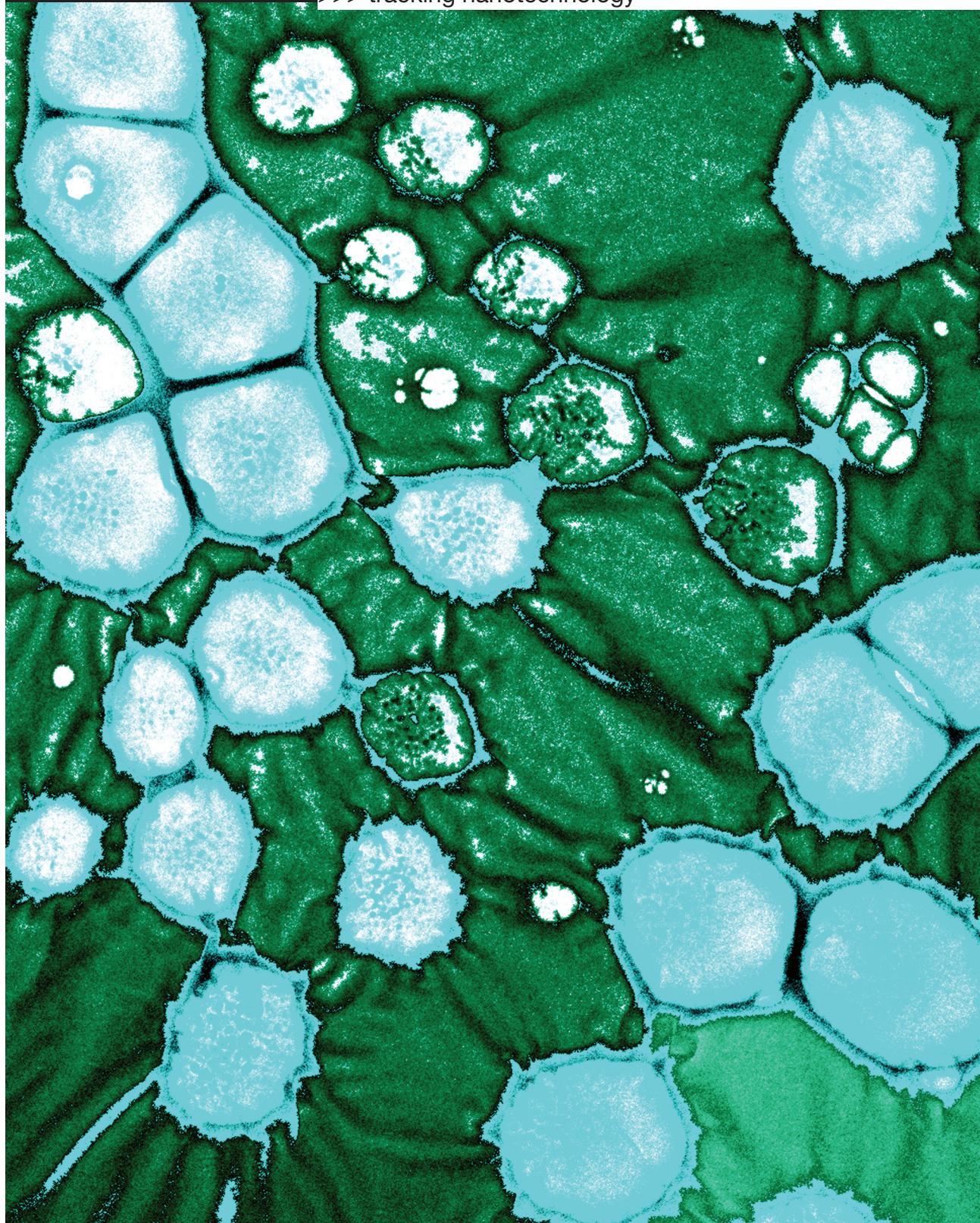
Source: Nokia researchers publish book on nanotechnology





nanoliki.info

>>> tracking nanotechnology



bibliography

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Dorothy Crowfoot Hodgkin: Structure as Art

by Robert Root-Bernstein¹

Leonardo, MIT Press Journals. Vol. 40, No. 3, 259–261 (2007). doi:10.1162/leon.2007.40.3.259

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Nanotechnology and in Situ Remediation: A Review of the Benefits and Potential Risks

by Barbara Karn¹, Todd Kuiken², Martha Otto¹

Environ Health Perspect 117:1823–1831(2009). doi:10.1289/ehp.0900793

1 U.S. Environmental Protection Agency, Washington, DC, USA

2 Woodrow Wilson International Center for Scholars, Project on Emerging Nanotechnologies, Washington, DC, USA

Ultra-High Porosity in Metal-Organic Frameworks

by Hiroyasu Furukawa¹, Nakeun Ko², Yong Bok Go¹, Naoki Aratani¹, Sang Beom Choi², Eunwoo Choi¹, A. Özgür Yazaydin³, Randall Q. Snurr³, Michael O’Keeffe¹, Jaheon Kim², Omar M. Yaghi^{1,4}
Science. Vol. 329 no. 5990 pp. 424–428 (2010). doi: 10.1126/science.1192160

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4 UCLA–Department of Energy (DOE) Institute of Genomics and Proteomics, UCLA, 607 Charles E. Young Drive East, Los Angeles, CA 90095, USA.

Green carbon as a bridge to renewable energy

by James M. Tour¹, Carter Kittrell¹, Vicki L. Colvin¹

Nature Materials. Vol. 9, pp 871–874 (2010). doi:10.1038/nmat2887

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Quantum entanglement in photosynthetic light-harvesting complexes

by Mohan Sarovar^{1,2}, Akihito Ishizaki^{2,3}, Graham R. Fleming^{2,3}, K. Birgitta Whaley^{1,2}
Nature Physics. Vol. 6, pp 462–467 (2010). doi:10.1038/nphys1652

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Long-Range Energy Propagation in Nanometre Arrays of Light Harvesting Antenna Complexes

by Maryana Escalante¹, Aufried Lenferink², Yiping Zhao^{3,4}, Niels Tas⁴, Jurriaan Huskens³, Neil Hunter⁵, Vinod Subramanian¹, Cees Otto²
Nano Letters, 10 (4), pp 1450–1457 (2010). doi: 10.1021/nl1003569

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A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO₂ films

by Brian O’Regan¹, Michael Grätzel¹

Nature 353, 737 – 740 (1991). doi:10.1038/353737a0

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Photoelectrochemical complexes for solar energy conversion that chemically and autonomously regenerate

by Moon-Ho Ham¹, Jong Hyun Choi², Ardemis A. Boghossian¹, Esther S. Jeng¹, Rachel A. Graff¹, Daniel A. Heller¹, Alice C. Chang¹, Aidas Mattis³, Timothy H. Bayburt³, Yelena V. Grinkova³, Adam S. Zeiger⁴, Krystyn J. Van Vliet⁴, Erik K. Hobbie⁵, Stephen G. Sligar³, Colin A. Wright³, Michael S. Strano¹

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High-performance lithium battery anodes using silicon nanowires

by Candace K. Chan¹, Hailin Peng², Gao Liu³, Kevin McIlwrath⁴, Xiao Feng Zhang⁴, Robert A. Huggins², Yi Cui²
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Nanoscale mapping of ion diffusion in a lithium-ion battery cathode

by N. Balke¹, S. Jesse¹, A. N. Morozovska², E. Eliseev³, D. W. Chung⁴, Y. Kim⁵, L. Adamczyk⁵, R. E. García⁴, N. Dudney⁵, S. V. Kalinin¹
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In Situ Observation of the Electrochemical Lithiation of a Single SnO₂ Nanowire Electrode

by Jian Yu Huang¹, Li Zhong², Chong Min Wang³, John P. Sullivan¹, Wu Xu⁴, Li Qiang Zhang², Scott X. Mao², Nicholas S. Hudak¹, Xiao Hua Liu¹, Arunkumar Subramanian¹, Hongyou Fan⁵, Liang Qi^{6,7}, Akihiro Kushima⁷ and Ju Li^{6,7}
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Experimental Realization of a Rotational Ratchet in a Granular Gas

by Peter Eshuis¹, Ko van der Weele², Detlef Lohse¹, Devaraj van der Meer¹
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Self-powered nanowire devices

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Conversion of carbon dioxide to methanol with silanes over N-heterocyclic carbene catalysts

by S. N. Riduan¹, Y. Zhang¹, J. Y. Ying¹
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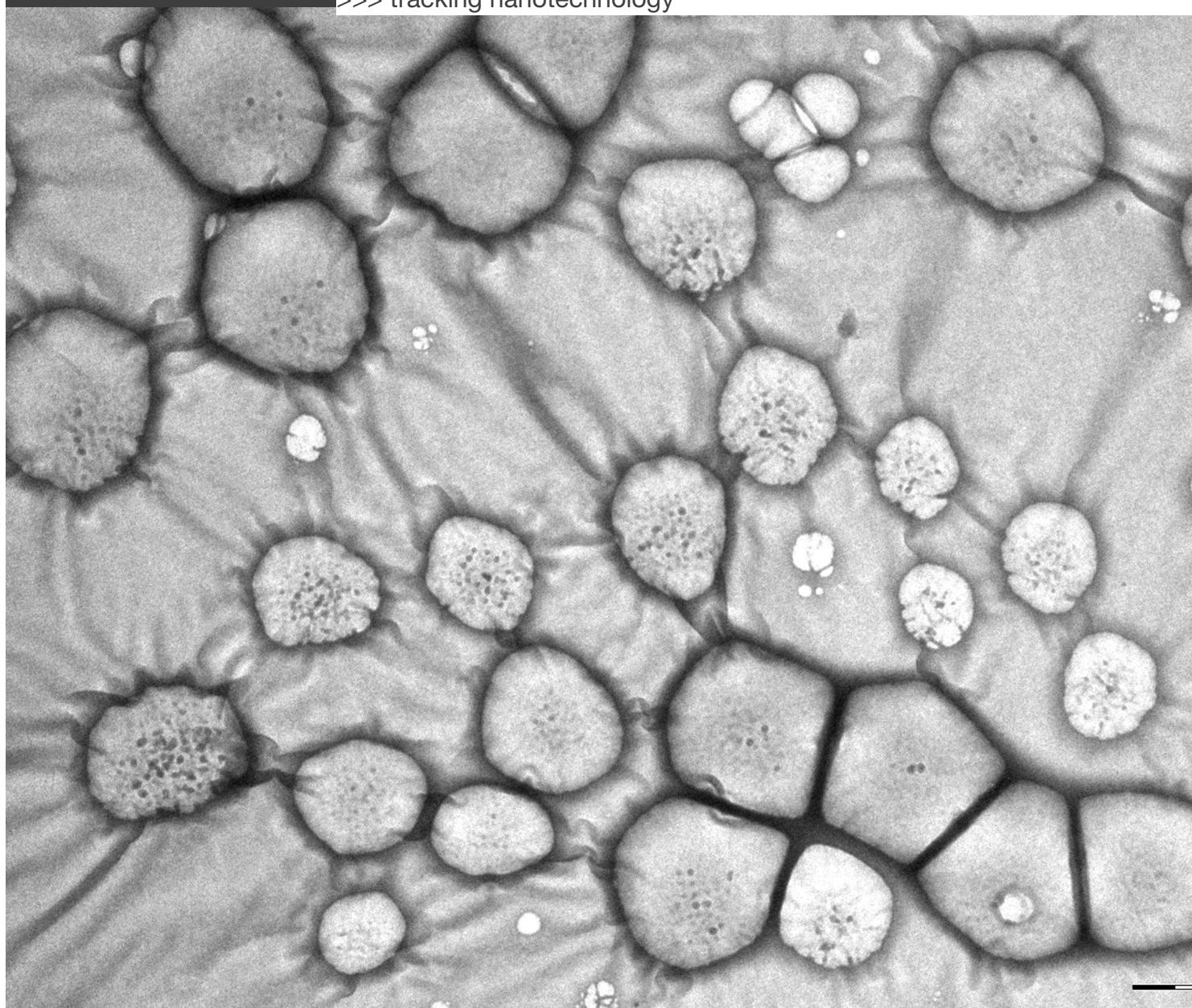
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epilogue

“ I was a third year medical student and from several books I had learned the details of the phenomenon mentioned, but these texts did not attract my attention although I felt they contained strong currents of thought. But when one of my friends, Mr Borao, Assistant of Physiology, kindly showed me the movement in the mesentery of the frog, in the presence of the sublime spectacle, I felt like I had a revelation. I was excited and touched to see red and white blood cells turn as pebbles to the momentum of the stream; seeing as, by virtue of their elasticity, the red cells stretched and passed laboriously through the finest capillaries and, the obstacle overcome, suddenly recovering their form in the manner of a spring, with a warning that, at the lowest obstacle in the current, joints of the endothelium would relax ensuing hemorrhage and edema; to notice, finally, how the heartbeat, weakened by the excessive action of curare, shook loose the stuck red blood cells ... it seemed like a veil was drawn back in my mind, and the belief in I do not know what mysterious force that was then attributed to the phenomena of life went away and was lost. In my enthusiasm I burst into the following statement, not knowing that many, notably Descartes, had expressed it centuries before: “Life resembles a pure mechanism. Living bodies are perfect hydraulic machines that are capable of repairing the disorders caused by the momentum of the stream that feeds them, and producing, under Generation, other similar hydraulic machines. “

Reglas y Consejos sobre Investigación Científica,
Santiago Ramon y Cajal, Nobel Laureate 1902, Physiology,







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A standard linear barcode is positioned above a series of numbers. The numbers are arranged in three groups: a leading digit '9', followed by '788461', and a trailing '532933'.